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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE
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VARIATIONS IN THE CAROTENE AND VITAMIN A CONTENTS OF QUEENSLAND BUTTERFATS

By R. J. W. GARTNER, B.Sc., Chemist, Biochemical Branch, Division of Animal Industry.

SUMMARY.

Data from a survey of the carotene and vitamin A contents of Queensland butterfats are presented.

Butter samples were submitted at fortnightly intervals in 1954 and 1955 from 12 dairying centres, predominantly in south-eastern Queensland. Each sample was representative of cream supplies received at the particular butter factory at the time of sampling.

The mean annual carotene, vitamin A and total vitamin A contents of Queensland butterfats were 12.8, 38.6 and 51.4 I.U./g. respectively. The mean proportion of total vitamin A potency due to carotene was 24.9 per cent.

Marked seasonal trends in the carotene, vitamin A and total vitamin A contents of butterfats were found in both years. Maximum values occurred between midwinter and early spring. Minimum values occurred between midsummer and early autumn.

There were no marked differences in the carotene and vitamin A contents of butterfats from the 12 centres. There were no marked differences between levels recorded in 1954 and 1955.

The average total vitamin A potency of Queensland butter in both summer and winter was higher than values published for other countries.

An examination of the influence of breed of dairy cattle showed that Australian Illawarra Shorthorn cows secrete less carotene and less carotenol pigments in butterfat than Jersey cows.

The marked seasonal variations in the total vitamin A potency of butterfat may be related to the stage of lactation and to other factors which affect production in the dairy cow. Variations do not appear to be a function of the level of carotene in the pasture ingested by the grazing animal.

I. INTRODUCTION.

The first extensive survey of the seasonal variation in the vitamin A potency of milk and butter produced and marketed in different regions was made in the United States of America (Cary 1947). In all but two of the 16 States examined there was a definite difference between the vitamin A potency of butter produced in winter and that of butter produced in summer. Winter butter had, on the average, two-thirds the vitamin A potency of summer butter.

In a survey of the vitamin A potency of New Zealand butter over three years, McDowell and McDowall (1953) found uniform and regularly recurring seasonal variations in both the carotene and vitamin A contents of the butterfats. Maximum values were found in late autumn, winter and early spring, with minimum values in late summer and early autumn. Summer butter had, on the average, four-fifths the vitamin A potency of winter butter.

The only previous investigation of the carotene and vitamin A content of Australian butterfat was conducted in Victoria by Farrer, Balding, Warren and Miller (1949). Analysing a limited number of samples taken at uneven intervals throughout the year, they found maximum values for total vitamin A potency in late winter or early spring; minimum values were found in late summer or early autumn.

This paper presents the results of a survey of the carotene and vitamin A contents of butter samples submitted from 12 dairying centres in Queensland. Except for unforeseen circumstances, samples were submitted at fortnightly intervals for two years.

The vitamin A potencies of the butters from individual centres and the five districts they represent are compared. Data on breeds, production, stage of lactation and rainfall were collected to determine whether the values found could be related to any of these factors.

II. METHODS.

(1) Sampling of Butters.

Twelve dairying centres were selected from which samples were submitted for analysis. These samples were also examined by Mitchell (1959) for softening point and iodine value. As shown in Fig. 1, the centres are predominantly in south-eastern Queensland, where the greatest concentration of dairy cattle occurs. Each centre contained one butter factory.

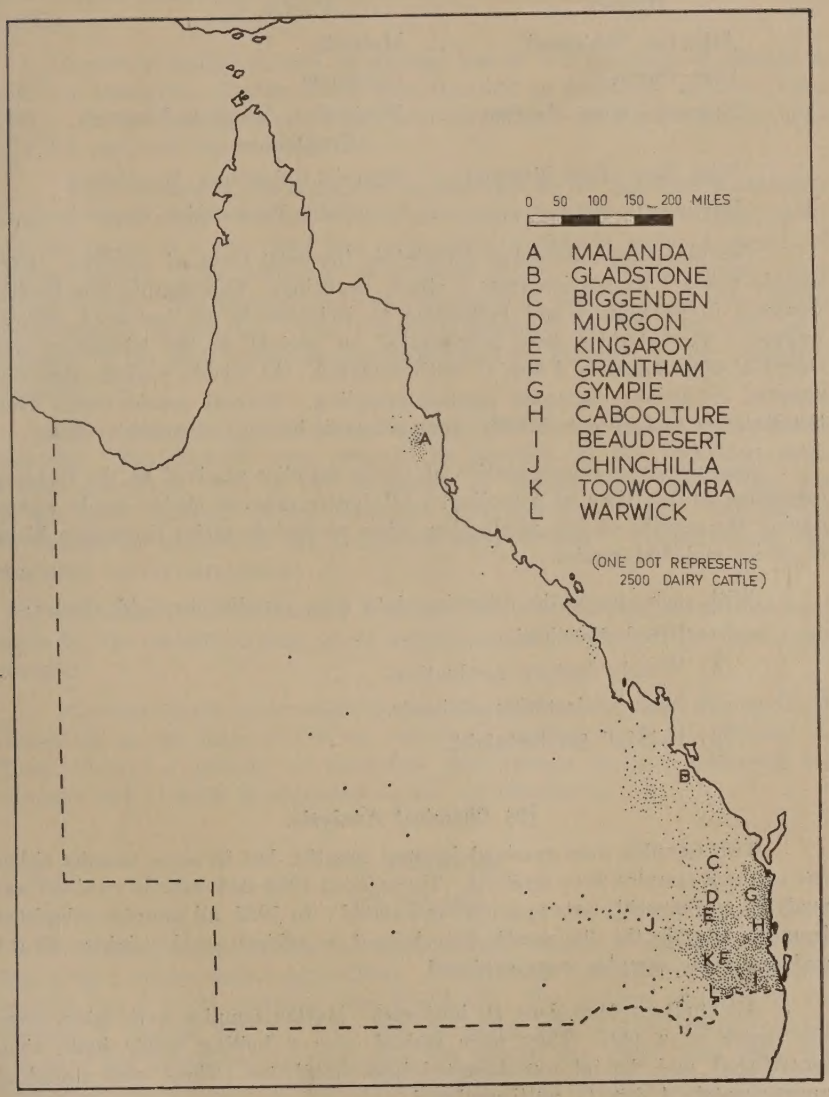

Fig. 1.

Map Showing Distribution of Dairy Cattle in Queensland and the Centres from Which Butter Samples Were Submitted.

The centres were grouped into districts as follows:—

District.	*Centre.*
Atherton Tableland ..	Malanda
Port Curtis	Gladstone
Burnett—West Moreton ..	Biggenden, Murgon, Kingaroy, Grantham
Wide Bay—East Moreton ..	Gympie, Caboolture, Beaudesert
Darling Downs	Chinchilla, Toowoomba, Warwick

Samples were collected at fortnightly intervals from all factories. Each sample was a 1 lb. portion from a single churning. This sample was double-wrapped in parchment and forwarded to Brisbane in an insulated railway waggon. The samples were refrigerated on arrival at the laboratory and stored at approximately 4 deg. C. until analysed. At certain periods abnormal seasonal conditions disrupted regular sampling. Several consignments from the Malanda factory deteriorated during transit because of excessive delay.

Samples were representative of cream supplies received at the factories concerned at the time of sampling. All butter was of choice grade except during the months of low production, when several factories churned a blend of choice and first grades.

With each sample the following data were supplied by field officers:—

(*a*) Breed distribution.

(*b*) Weekly factory production.

(*c*) Stage of lactation of herds.

(*d*) Rainfall for fortnight.

(2) Chemical Analysis.

Two samples were received in most months, but in some months either one or three samples were received. Throughout 1954 each sample received was analysed and monthly averages were calculated. In 1955, all samples submitted from a centre in the one month were bulked by taking equal weights (50 g.) and composite samples were analysed.

All analyses were done on butterfat. Butter samples were taken from the centre of a pat. They were melted over a boiling water bath, then centrifuged, and the fat was decanted into containers. These were stored at approximately 4 deg. C. until analysed.

The analytical saponification and extraction procedure was essentially that of McDowell (1949). Due to its greater stability with potassium hydroxide, methanol was used in the saponification rather than ethanol. Vitamin A was estimated on duplicate 10 ml. aliquots of the ether extract

(equivalent to 0·8 g. butterfat) by means of the Carr Price reaction. The photo-electric recording technique was that described by Gartner and Ryley (1956).

Recovery studies showed an average loss of 7·5 per cent. of vitamin A added to butterfat. Similar losses were recorded by American workers (Cary 1947). In the data presented below, corrections have been made on the basis of a 7·5 per cent. loss in vitamin A.

Total carotenoid was estimated on duplicate 10 ml. portions of the ether extract. Each aliquot was placed in a photometer test tube (2 cm. light path) and by means of a hot plate was evaporated to dryness under a stream of carbon dioxide. The pigments were taken up in 15 ml. petroleum ether (Shell X 222). The transmittance was measured at 440 mμ, using a Lumetron photo-electric colorimeter. The reference standard was 90 per cent. beta-carotene 10 per cent. alpha-carotene distributed by Eastman Kodak Company, Rochester, N.Y.

The method of Berl and Paterson (1943) was used to determine carotene. Xanthophylls were removed by partition of the petroleum ether extract previously used in the estimation of carotenoids. The solvent was 94 per cent. diacetone alcohol saturated with petroleum ether. This caused no change in volume of the petroleum ether extract. Transmittance was measured as for carotenoids.

In calculating the vitamin A content of the butterfats, corrections were made for the amount of blue colour contributed by carotene in the Carr Price reaction.

Carotene levels determined in micrograms were converted to vitamin A equivalent on the basis of 0·6 μg. carotene equivalent to 1 I.U. vitamin A. Total vitamin A potency of butterfats then became the sum potencies for carotene and vitamin A expressed as I.U. of vitamin A.

III. RESULTS.

(1) General.

Within any one month the carotene and vitamin A contents of butterfats from a centre varied appreciably. The average variation in the carotene content was 1·1 I.U. and the range 0–4·4 I.U. The average variation in the vitamin A content was 3·5 I.U. and the range 0–11·4 I.U. Only monthly averages are considered in presenting the results for 1954. For 1955, the results are representative of composite samples submitted in any one month.

The monthly averages for carotene, vitamin A and total vitamin A potency of butterfats are presented in Tables 1, 2 and 3 respectively. District and all centre averages are given in addition to average values for individual centres. The predominant breed of dairy cattle is shown for each centre and averages for centres with either predominantly Jersey, Australian Illawarra Shorthorn (A.I.S.) or mixed breeds are given.

Table 1.

MONTHLY CAROTENE CONCENTRATION OF BUTTERFATS FROM EACH CENTRE AND AVERAGES FOR DISTRICTS AND BREEDS (I.U./g).

Districts—Centres—Breeds.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
						1954.							
Atherton Tableland—													
***Malanda	8·7	12·8	11·1	10·2	10·5	10·6	11·6	11·1	11·3	11·0	10·2	10·0	10·8
Port Curtis—													
*Gladstone	12·8	18·0	14·2	10·5	10·5	10·4	10·9	13·7	16·2	14·4	13·3	13·2	13·2
Burnett–West Moreton—													
**Biggenden	11·1	13·5	14·0	10·6	10·1	†	†	14·8	12·8	15·5	14·2	12·8	
**Murgon	11·6	13·9	12·9	10·8	11·6	12·4	11·3	14·1	16·9	17·3	15·2	10·2	13·2
**Kingaroy	12·1	13·0	12·5	10·5	10·8	†	15·3	13·2	15·9	13·9	12·7	12·2	
**Grantham	13·1	14·8	12·9	9·0	8·9	9·9	10·3	13·9	15·3	14·1	14·0	11·3	12·3
District Average	12·0	13·8	13·1	10·2	10·4	11·2	12·3	14·0	15·2	15·2	14·0	11·6	12·8
Wide Bay–East Moreton—													
*Gympie	13·3	14·5	13·7	10·8	12·3	12·5	12·3	13·2	15·7	16·9	15·6	12·9	13·6
*Caboolture	12·5	16·1	14·0	11·8	12·1	12·2	11·8	13·4	15·4	15·5	14·6	11·8	13·4
**Beaudesert	11·7	15·0	14·4	10·8	10·1	10·5	12·2	13·9	15·0	14·8	15·0	10·9	12·9
District Average	12·5	15·2	14·0	11·1	11·5	11·7	12·1	13·5	15·4	15·7	15·1	11·9	13·3
Darling Downs—													
***Chinchilla	11·7	12·0	13·8	11·8	10·9	10·0	11·2	14·0	14·6	12·7	12·8	11·9	12·3
**Toowoomba	11·4	14·7	13·7	11·9	12·7	11·4	12·1	14·3	16·2	15·3	13·7	12·1	13·3
***Warwick	7·6	11·1	13·3	9·2	9·5	9·7	10·7	13·3	15·5	12·7	11·3	11·1	11·3
District Average	10·2	12·6	13·6	11·0	11·0	10·4	11·3	13·9	15·4	13·6	12·6	11·7	12·3
All Centres Average	11·5	14·1	13·4	10·7	10·8	11·0	11·8	13·6	15·1	14·5	13·6	11·7	12·7
*Predominantly Jersey Centres ..	12·9	16·2	14·0	11·0	11·6	11·7	11·7	13·4	15·8	15·6	14·5	12·6	13·4
**Mixed Breed Centres	11·8	14·2	13·4	10·6	10·7	11·1	12·2	14·0	15·4	15·2	14·1	11·6	12·9
***Predominantly A.I.S. Centres ..	9·3	12·0	12·7	10·4	10·3	10·1	11·2	12·8	13·8	12·1	11·4	11·0	11·4

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1955.

Atherton Tableland—												
***Malanda	9·8	10·0	12·7	10·8	11·2	11·0	10·2	11·3	†	†	†	†	
Port Curtis—													
*Gladstone	12·6	14·9	14·2	12·6	12·2	12·8	14·6	12·8	13·4	14·2	15·0	12·3	13·5
Burnett–West Moreton—													
**Biggenden	10·3	11·0	16·0	13·2	11·5	11·0	12·7	13·9	14·5	15·7	13·7	13·9	13·1
**Murgon	10·0	9·3	13·6	14·2	13·2	14·6	14·9	15·7	17·9	15·4	14·7	11·9	13·8
**Kingaroy	10·2	10·2	12·8	13·4	12·8	13·4	13·9	14·9	14·6	14·8	13·3	11·2	13·0
**Grantham	9·9	12·1	12·0	11·8	11·6	12·5	13·8	15·1	13·8	14·5	13·1	11·6	12·7
District Average	10·1	10·7	13·6	13·2	12·3	12·9	13·8	14·9	15·2	15·1	13·7	12·2	13·1
Wide Bay–East Moreton—													
*Gympie	10·6	14·1	14·3	13·2	12·8	12·3	13·8	14·6	13·8	16·1	15·4	13·4	13·7
*Caboolture	11·1	11·5	11·8	12·6	12·1	13·3	13·4	12·7	14·8	14·9	14·9	12·7	13·0
**Beaudesert	9·9	10·6	12·0	12·3	11·9	12·5	13·8	13·3	13·5	13·8	14·2	12·1	12·5
District Average	10·5	12·1	12·7	12·7	12·3	12·7	13·7	13·5	14·0	14·9	14·8	12·7	13·1
Darling Downs—													
***Chinchilla	10·2	10·1	11·5	10·9	11·1	14·8	14·5	15·5	16·2	12·0	†	11·5	
**Toowoomba	9·5	11·7	12·7	13·8	12·9	14·6	16·0	16·3	15·3	15·5	12·5	11·2	13·5
***Warwick	9·3	9·5	8·9	11·1	†	15·0	13·9	15·0	†	†	10·2	10·0	
District Average	9·7	10·4	11·0	11·9	12·0	14·8	14·8	15·6	15·8	13·8	11·4	10·9	12·7
All Centres Average	10·3	11·3	12·7	12·5	12·1	13·2	13·8	14·3	14·8	14·7	13·7	12·0	13·0
*Predominantly Jersey Centres ..	11·4	13·5	13·4	12·8	12·4	12·8	13·9	13·4	14·0	15·1	15·1	12·8	13·4
**Mixed Breed Centres	10·0	10·8	13·2	13·1	12·3	13·1	14·2	14·9	14·9	15·0	13·6	12·0	13·1
***Predominantly A.I.S. Centres ..	9·8	9·9	11·0	10·9	11·2	13·6	12·9	13·9	16·2	12·0	10·2	10·8	11·9
All Centres Average 1954–55 ..	10·9	12·7	13·1	11·6	11·5	12·1	12·8	14·0	15·0	14·6	13·7	11·9	12·8

† Samples unavailable.

Table 2.

MONTHLY VITAMIN A CONCENTRATION OF BUTTERFATS FROM EACH CENTRE AND AVERAGES FOR DISTRICTS AND BREEDS (I.U./g).

Districts—Centres—Breeds.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
						1954.							
Atherton Tableland—													
***Malanda	33·6	33·0	30·1	32·3	36·2	40·0	39·8	41·2	38·3	38·3	35·1	28·4	35·5
Port Curtis—													
*Gladstone	23·0	28·7	28·0	32·7	35·0	42·5	46·3	48·2	46·1	41·2	37·7	37·8	37·3
Burnett–West Moreton—													
**Biggenden	31·7	27·5	29·2	32·6	41·5	†	†	44·5	46·9	34·3	37·2	34·2	
**Murgon	31·2	31·2	29·3	35·9	41·3	40·8	49·0	46·3	44·9	39·9	34·0	28·0	37·7
**Kingaroy	35·0	30·5	31·5	34·9	39·1	†	52·6	47·2	40·4	40·3	35·5	33·5	
**Grantham	32·8	33·0	31·3	33·0	37·2	42·5	51·0	45·1	43·2	35·0	35·3	33·2	37·7
District Average	32·7	30·6	30·3	34·1	39·8	41·7	50·9	45·8	43·9	37·4	35·5	32·2	37·9
Wide Bay–East Moreton—													
*Gympie	28·0	30·1	29·6	32·9	39·1	42·9	48·1	48·7	46·8	43·1	32·3	30·8	37·7
*Caboolture	27·5	29·7	28·4	31·4	33·5	37·9	45·8	45·2	44·9	36·9	36·7	30·7	35·7
**Beaudesert	38·7	36·7	29·9	31·9	39·3	45·9	50·5	50·1	44·0	39·5	35·0	31·1	39·4
District Average	31·4	32·2	29·3	32·1	37·3	42·2	48·1	48·0	45·2	39·8	34·7	30·9	37·6
Darling Downs—													
***Chinchilla	29·9	38·4	28·2	35·0	40·3	38·6	44·7	48·4	42·8	38·3	36·9	33·0	37·9
**Toowoomba	37·8	32·1	33·6	29·9	38·0	37·5	43·5	45·0	41·1	35·2	35·3	31·2	36·7
***Warwick	37·4	42·6	32·3	35·1	32·9	41·3	47·7	50·0	45·1	38·9	36·5	36·0	39·7
District Average	35·0	37·7	31·4	33·3	37·1	39·1	45·3	47·8	43·0	37·5	36·2	33·4	38·1
All Centres Average	32·2	32·8	30·1	33·1	37·8	41·0	47·2	46·7	43·7	38·4	35·6	32·3	37·6
*Predominantly Jersey Centres ..	26·2	29·5	28·7	32·3	35·9	41·1	46·7	47·4	45·9	40·4	35·6	33·1	36·9
**Mixed Breed Centres	34·5	31·8	30·8	33·0	39·4	41·7	49·3	46·4	43·4	37·4	35·4	31·9	37·9
***Predominantly A.I.S. Centres ..	33·6	38·0	30·2	34·1	36·5	40·0	44·1	46·5	42·1	38·5	36·2	32·5	37·7

Atherton Tableland—													
***Malanda	36·1	37·3	35·4	32·3	36·3	36·3	40·8	37·6	†	†	†	†	
Port Curtis—													
*Gladstone	34·5	29·0	29·1	32·8	35·6	39·0	44·3	41·8	49·4	46·9	42·0	39·6	38·7
Burnett–West Moreton—													
**Biggenden	29·3	31·5	29·6	33·1	36·8	42·6	47·0	49·1	49·0	50·2	40·1	33·0	39·3
**Murgon	30·1	34·0	31·3	36·1	41·8	45·4	51·0	43·8	48·4	41·6	35·1	39·2	39·8
**Kingaroy	30·8	36·3	33·9	39·0	44·2	48·0	50·7	45·4	42·4	36·7	37·9	39·2	40·4
**Grantham	31·8	31·4	27·4	36·5	36·6	43·9	48·7	51·9	44·7	46·5	36·4	37·0	39·4
District Average	30·5	33·3	30·6	36·2	39·9	45·0	49·4	47·6	46·1	43·8	37·4	37·1	39·7
Wide Bay–East Moreton—													
*Gympie	29·4	30·4	27·0	30·9	33·3	44·5	49·9	55·6	52·0	47·3	41·6	33·1	39·6
*Caboolture	32·7	31·1	29·3	33·9	36·4	36·4	45·2	46·8	49·3	46·1	37·3	34·8	38·3
**Beaudesert	31·1	31·5	30·7	35·8	39·7	46·2	53·1	53·5	47·8	42·9	37·4	33·3	40·3
District Average	31·1	31·0	29·0	33·5	36·5	42·4	49·4	52·0	49·7	45·4	38·8	33·7	39·4
Darling Downs—													
***Chinchilla	35·6	37·7	34·0	41·5	47·2	47·6	55·7	53·7	47·6	32·7	†	35·3	
**Toowoomba	33·1	27·8	31·1	36·6	40·2	44·1	52·2	47·0	38·5	36·4	33·0	33·0	37·8
***Warwick	32·6	30·4	31·4	41·6	†	45·6	54·5	51·1	†	†	40·3	40·8	
District Average	33·8	32·0	32·2	39·9	43·7	45·8	54·1	50·6	43·1	34·6	36·7	36·4	40.2
All Centres Average	32·3	32·4	30·9	35·8	38·9	43·3	49·4	48·1	46·9	42·7	38·1	36·2	39·6
*Predominantly Jersey Centres ..	32·2	30·2	28·5	32·5	35·1	40·0	46·5	48·1	50·2	46·8	40·3	35·8	38·9
**Mixed Breed Centres	31·0	32·1	30·7	36·2	39·9	45·0	50·5	48·5	45·1	42·4	36·7	35·8	39·5
***Predominantly A.I.S. Centres ..	34·8	35·1	33·6	38·5	41·8	43·2	50·3	47·5	47·6	32·7	40·3	38·1	40·3
All Centres Average 1954–1955 ..	32·3	32·6	30·5	34·5	38·4	42·2	48·3	47·4	45·3	40·6	36·9	34·3	38·6

† Samples unavailable.

Table 3.

MONTHLY TOTAL VITAMIN A POTENCY OF BUTTERFATS FROM EACH CENTRE AND AVERAGES FOR DISTRICTS AND BREEDS (I.U./g).

Districts—Centres—Breeds.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
						1954.							
Atherton Tableland—													
***Malanda	42·3	45·8	41·2	42·5	46·7	50·6	51·4	52·3	49·6	49·3	45·3	38·4	46·3
Port Curtis—													
*Gladstone	35·8	46·7	42·2	43·2	45·5	52·9	57·2	61·9	62·3	55·6	51·0	51·0	50·5
Burnett–West Moreton—													
**Biggenden	42·8	41·0	43·2	43·2	51·6	†	†	59·3	59·7	49·8	51·4	47·0	
**Murgon	42·8	45·1	42·2	46·7	52·9	53·2	60·3	60·4	61·8	57·2	49·2	38·2	50·9
**Kingaroy	47·1	43·5	44·0	45·4	49·9	†	67·9	60·4	56·3	54·2	48·2	45·7	
**Grantham	45·9	47·8	44·2	42·0	46·1	52·4	61·3	59·0	58·5	49·1	49·3	44·5	50·0
District Average	44·7	44·4	43·4	44·3	50·2	52·9	63·2	59·8	59·1	52·6	49·5	43·8	50·7
Wide Bay–East Moreton—													
*Gympie	41·3	44·6	43·3	43·7	51·4	55·4	60·4	61·9	62·5	60·0	47·9	43·7	51·3
*Caboolture	40·0	45·8	42·4	43·2	45·6	50·1	57·6	58·6	60·3	52·4	51·3	42·5	49·1
**Beaudesert	50·4	51·7	44·3	42·7	49·4	56·4	62·7	64·0	59·0	54·3	50·0	42·0	52·3
District Average	43·9	47·4	43·3	43·2	48·8	53·9	60·2	61·5	60·6	55·5	49·8	42·8	50·9
Darling Downs—													
***Chinchilla	41·6	50·4	42·0	46·8	51·2	48·6	55·9	62·4	57·4	51·0	49·7	44·9	50·2
**Toowoomba	49·2	46·8	47·3	41·8	50·7	48·9	55·6	59·3	57·3	50·5	49·0	43·3	50·0
***Warwick	45·0	53·7	45·6	44·3	42·4	51·0	58·4	63·3	60·6	51·6	47·8	47·1	51·0
District Average	45·2	50·3	45·0	44·3	48·1	49·5	56·6	61·7	58·4	51·1	48·8	45·1	50·4
All Centres Average	43·7	46·9	43·5	43·8	48·6	52·0	59·0	60·3	58·8	52·9	49·2	44·0	50·3
*Predominantly Jersey Centres ..	39·1	45·7	42·7	43·3	47·5	52·8	58·4	60·8	61·7	56·0	50·1	45·7	50·3
**Mixed Breed Centres	46·3	46·0	44·2	43·6	50·1	52·8	61·5	60·4	58·8	52·6	49·5	43·5	50·8
***Predominantly A.I.S. Centres ..	42·9	50·0	42·9	44·5	46·8	50·1	55·3	59·3	55·9	50·6	47·6	43·5	49·1

1955.

Atherton Tableland—													
***Malanda	45·9	47·3	48·1	43·1	47·5	47·3	51·0	48·9	†	†	†	†	
Port Curtis—													
*Gladstone	47·1	43·9	43·3	45·4	47·8	51·8	58·9	54·6	62·8	61·1	57·0	51·9	52·2
Burnett–West Moreton—													
**Biggenden	39·6	42·5	45·6	46·3	48·3	53·6	59·7	63·0	63·5	65·9	53·8	46·9	52·4
**Murgon	40·1	43·3	44·9	50·3	55·0	60·0	65·9	59·5	66·3	57·0	49·8	51·1	53·6
**Kingaroy	41·0	46·5	46·7	52·4	57·0	61·4	64·6	60·3	57·0	51·5	51·2	50·4	53·4
**Grantham	41·7	43·5	39·4	48·3	48·2	56·4	62·5	67·0	58·5	61·0	49·5	48·6	52·1
District Average	40·6	44·0	44·2	49·4	52·2	57·9	63·2	62·5	61·3	58·9	51·1	49·3	52·8
Wide Bay–East Moreton—													
*Gympie	40·0	44·5	41·3	44·1	46·1	56·8	63·7	70·2	65·8	63·4	57·0	46·5	53·3
*Caboolture	43·8	42·6	41·1	46·5	48·5	49·7	58·6	59·5	64·1	61·0	52·2	47·5	51·3
**Beaudesert	41·0	42·1	42·7	48·1	51·6	58·7	66·9	66·8	61·3	56·7	51·6	45·4	52·8
District Average	41·6	43·1	41·7	46·2	48·8	55·1	63·1	65·5	63·7	60·3	53·6	46·4	52·5
Darling Downs—													
***Chinchilla	45·8	47·8	45·5	52·4	58·3	62·4	70·2	69·2	63·8	44·7	†	46·8	
**Toowoomba	42·6	39·5	43·8	50·4	53·1	58·7	68·2	63·3	53·8	51·9	45·5	44·2	51·3
***Warwick	41·9	39·9	40·3	52·7	†	60·6	68·4	66·1	†	†	50·5	50·8	
District Average	43·5	42·4	43·2	51·8	55·7	60·6	68·9	66·2	58·9	48·4	48·1	47·3	52·9
All Centres Average	42·6	43·7	43·6	48·3	51·0	56·5	63·2	62·4	61·7	57·4	51·8	48·2	52·6
*Predominantly Jersey Centres ..	43·6	43·7	41·9	45·3	47·5	52·8	60·4	61·5	64·2	61·9	55·4	48·6	52·3
**Mixed Breed Centres	41·0	42·9	43·9	49·3	52·2	58·1	64·7	63·4	60·0	57·4	50·3	47·8	52·6
***Predominantly A.I.S. Centres ..	44·6	45·0	44·6	49·4	53·0	56·8	63·2	61·4	63·8	44·7	50·5	48·9	52·2
All Centre Average 1954–1955 ..	43·2	45·3	43·6	46·1	49·9	54·3	61·1	61·4	60·3	55·2	50·6	46·2	51·4

† Samples unavailable.

Differences in monthly values are relatively large in each centre due to marked seasonal trends. Thus yearly averages have not been calculated for centres with incomplete samples. However, the smaller differences between centres in any one month permitted the calculation of monthly and yearly averages for districts without introducing appreciable errors. Monthly and yearly averages of centres with similar breed distribution are also presented.

(2) Seasonal Trends.

The seasonal trends in the carotene, vitamin A and total vitamin A contents in butterfats are shown in Figs. 2–13 for individual centres and in Fig. 14 as an average for all centres. In addition, butter production is presented in Fig. 14 as a monthly percentage of the total annual production. These production percentages have been calculated from individual factory production and are given as an average for all centres.

Most centres showed the same pattern, with peaks of similar magnitude occurring at approximately the same time of the year. The exception was Malanda (Fig. 2), where the annual average vitamin A and total vitamin A potency were lower than for any other centre and the values showed less well defined peaks.

(*a*) *Maximum Values.*—Maximum values for carotene in butterfats occurred generally between the end of winter and mid-spring (August–October).

Maximum values for vitamin A and total vitamin A occurred between midwinter and early spring (July to September).

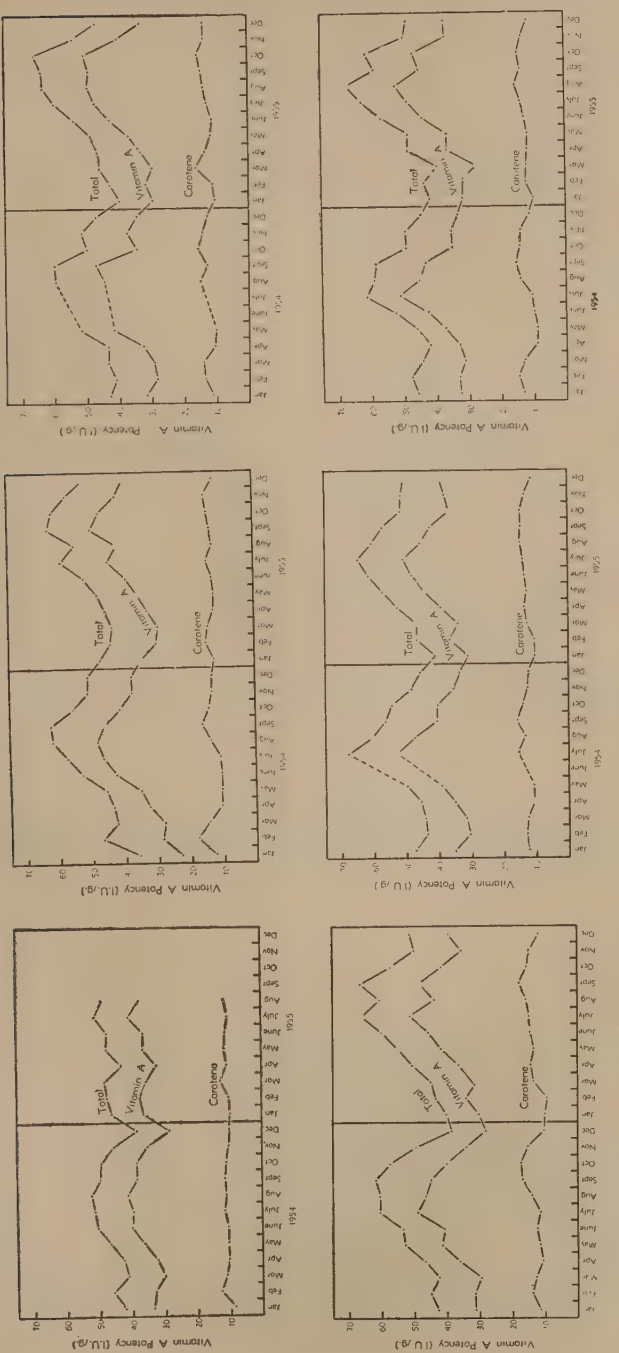
Maximum values for vitamin A preceded those of carotene by one month in both years.

(*b*) *Minimum Values.*—In 1954, minimum values for carotene in butterfat occurred between mid-autumn and early winter (April–June).

In 1955 they occurred in summer (December 1954–February 1955).

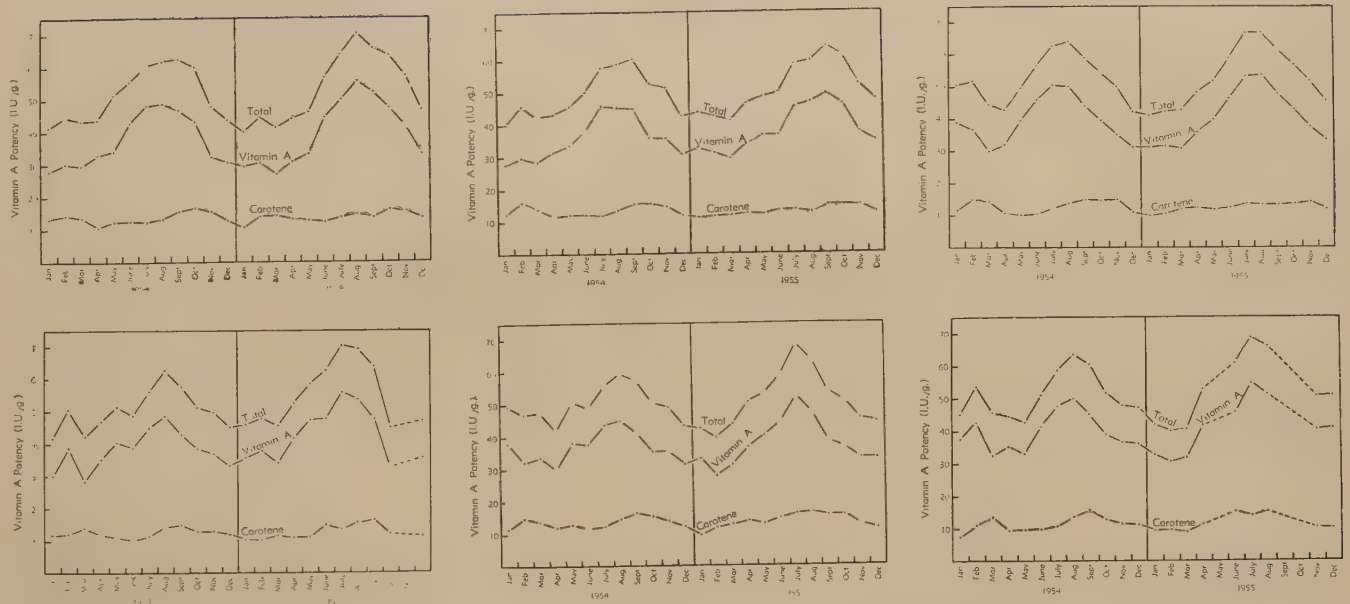
In both years, minimum values for vitamin A and total vitamin A potency occurred between midsummer and early autumn (January–March).

Minimum vitamin A values preceded minimum carotene values by three months in 1954. In 1955, they succeeded them by one month.



Figs. 2–7.

Seasonal Trends in Carotene, Vitamin A and Total Vitamin A Contents of Butterfats from (left to right) Malanda, Gladstone, Biggenden, Murgon, Kingaroy and Grantham.



Figs. 8–13.

Seasonal Trends in Carotene, Vitamin A and Total Vitamin A Contents of Butterfats from (left to right) Gympie, Caboolture, Beaudesert, Chinchilla, Toowoomba and Warwick.

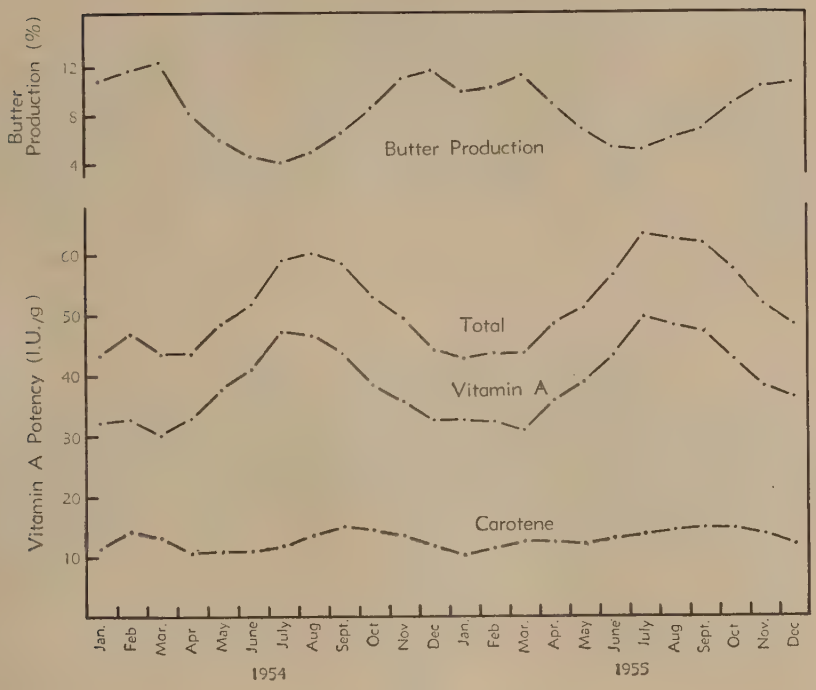


Fig. 14.

Seasonal Trends in the Carotene, Vitamin A and Total Vitamin A Contents of Queensland Butterfats. Butter production is shown as monthly percentages of the total annual production (average of 12 centres).

(3) Weighted Mean Annual Contents of Carotene, Vitamin A and Total Vitamin A.

Although butter production in Queensland follows a seasonal trend (Fig. 14), the difference in production levels between successive fortnightly samples is not great. Thus the monthly carotene, vitamin A and total vitamin A contents of butterfats have not been weighted for production. The weighted mean annual contents for these values do not vary greatly from the unweighted means, as shown in Table 4.

Table 4.

Weighted and Unweighted Mean Annual Contents of Carotene, Vitamin A and Total Vitamin A in Queensland Butterfats.

	Unweighted Mean Annual Content in Butterfat. (I.U./g.)		Weighted Mean Annual Content in Butterfat. (I.U./g.)	
	1954.	1955.	1954.	1955.
Carotene	12·7	13·0	12·7	12·8
Vitamin A	37·6	39·6	35·8	38·2
Total Vitamin A Potency	50·3	52·6	48·5	51·0

(4) Xanthophyll Content of Butterfats.

From July 1954 to December 1955, total carotenoids were determined in butterfats. The difference between total carotenoids and carotene was recorded as xanthophyll. The average monthly values for the 12 centres are presented in Fig. 15.

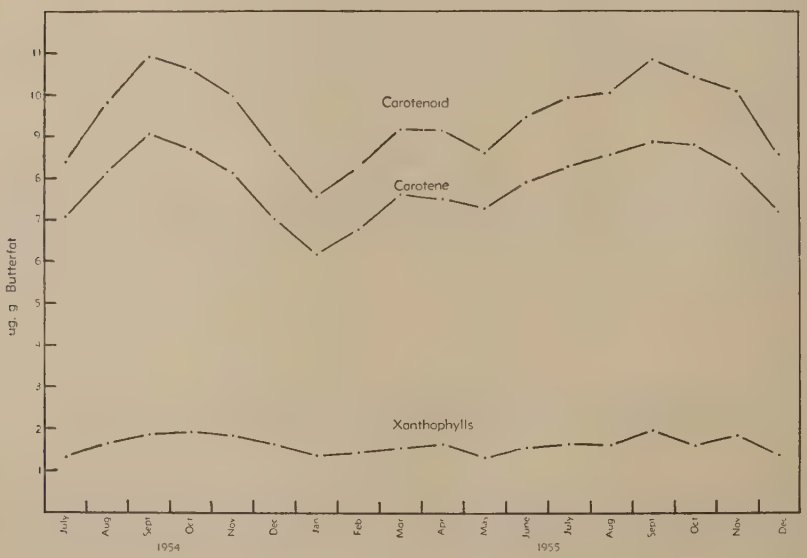


Fig. 15.

Xanthophyll, Carotene and Carotenoid Contents of Queensland Butterfats (Average of 12 Centres).

(5) Proportion of Total Vitamin A Potency in Butterfats Due to Carotene.

The seasonal variations in the total vitamin A potency of butterfats were much greater than the variations in carotene (Fig. 14). The proportion of the total vitamin A potency due to carotene is thus inversely correlated with the total vitamin A potency. This proportion can be obtained from Tables 1 and 3. The mean value for all the 12 centres was 25·2 per cent. in 1954 and 24·7 per cent. in 1955.

(6) Variations Between Centres and Districts.

With the exception of Malanda, differences between centres and between districts were small in terms of carotene, vitamin A and total vitamin A content of butterfats. The values for Malanda butterfat were lower than for any other centre in 1954. The same trend was apparent in 1955, although average annual values were not estimated because samples covering the last four months of the year were unsuitable for analysis.

(7) Variations Between Years.

Climatic conditions for the two years of the survey promoted good pasture growth. Marked variations in the analytical data from one year to the other were not obtained. In fact, the annual averages for carotene, vitamin A and total vitamin A potency of butterfat were similar for most centres in both years.

(8) Variations Between Breeds.

(*a*) *In Carotene Content of Butterfat.*—The dairy cattle population of the 12 centres consisted predominantly of two breeds: Jersey and A.I.S. cattle. In Table 5, the estimated breed distribution is given for each centre, together with mean values for the proportion of total vitamin A potency due to carotene and mean values for the carotene content of butterfats.

Table 5.

BREED DISTRIBUTION IN EACH CENTRE, MEAN VALUES FOR PROPORTION OF TOTAL VITAMIN A POTENCY DUE TO CAROTENE IN BUTTERFATS, AND MEAN VALUES FOR CAROTENE CONTENT OF BUTTERFATS.

Centre.	Breed.			1954.		1955.	
	Jersey.	A.I.S.	Mixed.	Proportion Total Potency due to Carotene.	Carotene. I.U./g. Butterfat.	Proportion Total Potency due to Carotene.	Carotene. I.U./g. Butterfat.
	%	%	%	%		%	
Gladstone ..	98	..	2	26·1	13·2	25·9	13·5
Caboolture ..	80	15	5	27·3	13·4	25·3	13·0
Gympie	75	20	5	26·5	13·6	25·7	13·7
Kingaroy ..	50	50	..	25·2†	12·9†	24·3	13·0
Biggenden ..	50*	40	10	..	..	25·0	13·1
Beaudesert ..	47	50	3	24·7	12·9	23·7	12·5
Toowoomba ..	40	58	2	26·6	13·3	26·3	13·5
Murgon	40	60	..	25·9	13·2	25·7	13·8
Grantham ..	40	60	..	24·6	12·3	24·4	12·7
Malanda	35	65	..	23·3	10·8	..	..
Chinchilla ..	25	75	..	24·5	12·3	22·8†	12·6†
Warwick ..	25	75	..	22·1	11·3	..	..

* Consisting of 40 per cent. Jersey, 10 per cent. Guernsey breed.

† Average of 11 months.

It appears from Table 5 that there is a relationship between breed and the proportion of total vitamin A due to carotene. This is examined statistically in Table 6A.

Table 6A.

SUMMARY OF ANALYSES OF VARIANCE—PROPORTION OF TOTAL VITAMIN A POTENCY IN BUTTERFATS DUE TO CAROTENE AND PERCENTAGE JERSEY BREED.

Source of Variation.	1954.		1955.	
	Degrees of Freedom.	Mean Squares.	Degrees of Freedom.	Mean Squares.
Linear Regression	1	174·005†	1	45·437
Deviations	9	17·566	8	11·658
Between Centres	10	33·210	9	15·411
Regression Coefficient ..		0·0508		0·0290

† Significant at 5 per cent. level.

In Table 6B the relationship between breed and carotene content of butterfat is examined statistically.

Table 6B.

SUMMARY OF ANALYSES OF VARIANCE—CAROTENE CONTENT OF BUTTERFATS AND PERCENTAGE JERSEY BREED.

Source of Variation.	1954.		1955.	
	Degrees of Freedom.	Mean Squares.	Degrees of Freedom.	Mean Squares.
Linear Regression	1	40·035†	1	3·129
Deviations	9	6·847	8	2·487
Between Centres	10	10·166	9	2·559
Regression Coefficient ..		0·0243		0·0076

† Significant at 5 per cent. level.

The variance within districts was not calculated due to the marked seasonal trends encountered both in the carotene and in the total vitamin A content of butterfats. For this reason also, centres with more than one monthly value missing were excluded from the analysis (Table 5).

In 1954, butterfat from centres with predominantly Jersey cattle contained a significantly greater proportion of total vitamin A potency due to carotene and a significantly greater carotene content compared with centres with predominantly A.I.S. cattle. In 1955, there were no significant correlations between these variates.

There was no correlation between breed and either the vitamin A or the total vitamin A potency of butterfats.

(*b*) *In the Proportion of Carotene to Total Carotenoids in Butterfats.*—The mean value for the proportion of carotene to total carotenoids, together with the estimated breed distribution, is given for each centre in Table 7. The proportion of carotene to total carotenoids ranged from 74·1 to 94·5 per cent., the average being 82·7±2·8 per cent.

Table 7.

Breed Distribution in Each Centre and Mean Values for the Proportion of Carotene to Total Carotenoids in Butterfats.

Centre.	Breed.			Ratio Carotene to Carotenoids.	Number of Samples.
	Jersey.	A.I.S.	Mixed.		
	%	%	%	%	
Gladstone	98	..	2	80·4	17
Caboolture	80	15	5	79·5	18
Gympie	75	20	5	79·9	18
Kingaroy	50	50	..	83·6	18
Biggenden	50*	40	10	80·1	17
Beaudesert	47	50	3	83·9	18
Toowoomba	40	58	2	85·6	18
Murgon	40	60	..	82·2	18
Grantham	40	60	..	84·6	18
Malanda	35	65	..	81·0	15
Chinchilla	25	75	..	85·5	17
Warwick	25	75	..	86·5	16

* Consisting of 40 per cent. Jersey, 10 per cent. Guernsey breed.

The relationship between breed and the proportion of carotene to total carotenoids is examined statistically in Table 8. There was no seasonal trend in the proportion, but there was variation within districts.

Table 8.

Summary of Analyses of Variance—Proportion of Carotene to Total Carotenoids in Butterfats and Percentage Jersey Breed.

Source of Variation.	Degrees of Freedom.	Mean Squares.
Linear Regression	1	666·97††
Deviations	10	53·92††
Between Centres	11	109·66††
Within Centres	196	7·62
Regression Coefficient ..		−0·0833

†† Significant at 1 per cent. level.

Butterfat from centres with predominantly Jersey cattle contained a significantly smaller proportion of carotene to total carotenoids than centres with predominantly A.I.S. cattle.

(9) Comparison of Total Vitamin A Potency of Queensland Butterfat with Values from Other Regions.

When comparing the annual average total vitamin A potency of butterfat and butter obtained in this survey with values for other regions, consideration must be given to climatic conditions. In Queensland, cattle graze throughout the year and pastures are the main source of feed.

In Europe and in most parts of the United States of America, cattle are stall-fed in winter. In the absence of continuous grazing the potency of the winter butterfat falls (Table 10), resulting in a lowering of the annual average vitamin A potency. In Table 9, the average total vitamin A potency of butterfat and butter is presented for some regions where stock graze continuously throughout the year.

Table 9.

AVERAGE TOTAL VITAMIN POTENCY OF BUTTERFAT AND BUTTER FROM SOME REGIONS WHERE GRAZING IS PRACTISED THROUGHOUT THE YEAR.

Region.	Year.	Vitamin A Potency. I.U./g. Butterfat.	Vitamin A Potency. I.U./lb. Butter†.	Proportion Potency due to Carotene.	Authority.
Victoria††	1947–48	45·2	16800	35·0–40·0	Farrer *et al.* 1949
New Zealand ..	1946–48	45·0	16740	36·8	McDowell and McDowall 1953
Queensland ..	1954–55	51·4	19100	24·9	..

† Calculated as butter containing 82 per cent. butterfat.

†† These values are estimated from the data presented in Table 1 of this paper. They have been corrected for a 7·5 per cent. analytical loss of vitamin A to conform with the succeeding values on the assumption that 37·5 per cent. of the total vitamin A potency was due to carotene.

It is of interest to compare the vitamin A potency of winter and summer butter in different countries. The data for New Zealand, Great Britain, Sweden and Denmark have been reproduced from McDowell and McDowall (1953) and are presented in Table 10, together with data from the United States of America and Queensland.

Table 10.

COMPARISON OF TOTAL VITAMIN A POTENCIES OF BUTTER IN DIFFERENT COUNTRIES.

Country.	Total Vitamin A Potency expressed as			
	I.U./g.		I.U./lb.	
	Winter Butter.	Summer Butter.	Winter Butter.	Summer Butter.
New Zealand	41·9	33·8	19,010	15,330
Great Britain†	18·5	29·0	8,390	13,150
Sweden**	15·0	24·2	6,800	10,980
Denmark***	16·5	33·1	7,480	15,010
U.S.A.*	20·1	32·9	9,120	14,900
Queensland††	45·4	34·7	20,590	15,740

† Calculated from values published by Thompson, Ganguley, Mawson & Kon (1949) for carotene and vitamin A contents of milk in Great Britain. The assumption has been made that 80 per cent. of the total carotenoids in the summer milks and 75 per cent. of the total in the winter milks examined was active carotene.

** Platon & Swartling (1944).

*** Fridericia (1947).

* Recalculated from the uncorrected values published by Cary (1947) and based on a factor of 3·33 instead of 4.0 for the conversion of vitamin A expressed in micrograms into international units. It was assumed that 20 per cent. of the potency was due to carotene for both winter and summer butter.

†† These values are uncorrected for analytical losses to conform with the preceding values and are calculated on the basis of butter containing 82 per cent. butterfat.

(10) Correlation of Butter Production Ratio and Total Vitamin A Potency of Butterfat.

Weekly butter production records were obtained from each factory. The monthly butter production for each centre was assessed from these records and expressed as a percentage of the annual production. The monthly percentages of the 12 centres were then combined and expressed as an overall average for each month of the particular year. Finally, the monthly butter production percentages were averaged for the two years.

Production percentages are to some extent a function of the number of cows lactating in any one month. To relate monthly production to the total vitamin A potency of butterfat, some means of correction for the different number of cows lactating per month had to be considered.

This was achieved through access to herd recording data for the years 1948–1955, comprising records from one to three areas in each centre. The number of cows lactating per month was obtained by reference to the number calving per month and their average length of lactation. The number lactating per month was expressed as a percentage of the total number lactating per year. The monthly percentages of the 12 centres were then combined and expressed as an overall average for each month. The cows in the herd recording scheme were considered representative of all cows in a centre, though in most cases they were only a small percentage of the population.

The production percentages were then adjusted by taking into account the proportion of cows lactating per month in the following manner:

$$\text{Butter production ratio} = \frac{\text{Percentage butter produced in any one month}}{\text{Percentage cows lactating in same month}}$$

In Fig. 16, the production ratio is presented together with the total vitamin A potency as a 2-year average for the 12 centres. There is a highly significant inverse correlation ($r = -0{\cdot}754$, $P = < 0{\cdot}01$) between the values.

(11) Correlation of the Proportion of Cows Calving and the Total Number of Lactating Cows in Any One Month and Total Vitamin A Potency of Butterfat.

This proportion was determined from the herd recording data from each centre and expressed in monthly percentages as an average for 12 centres.

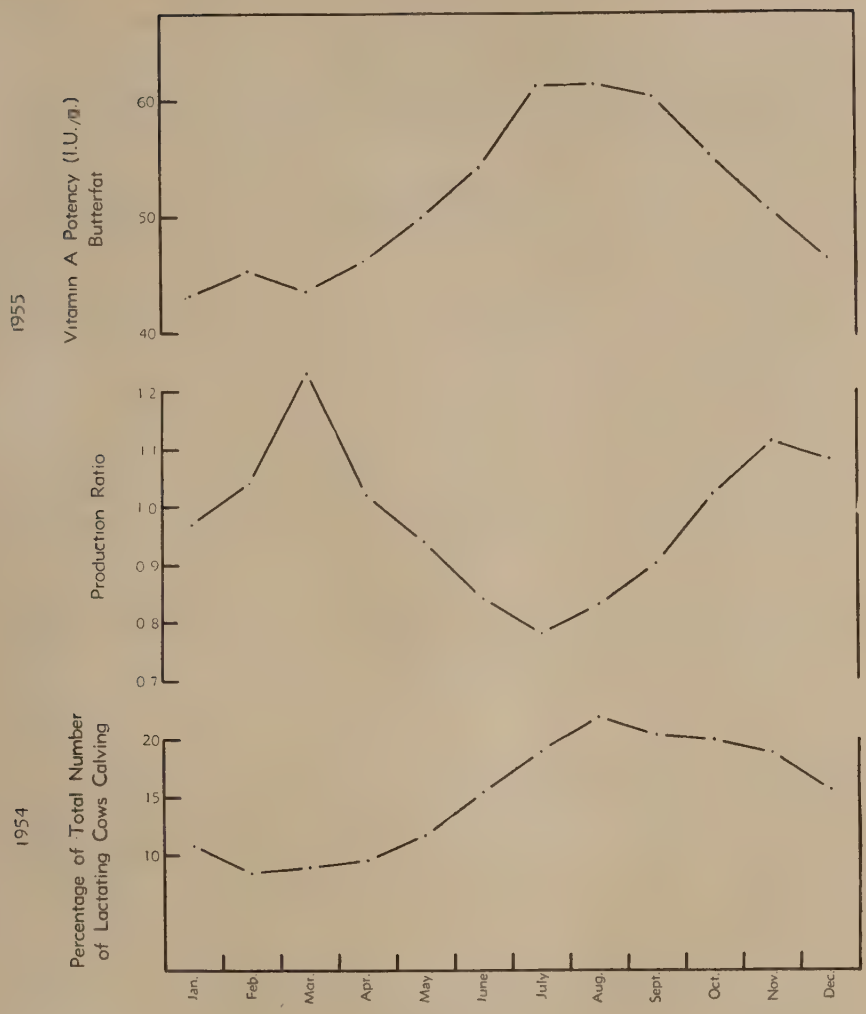


Fig. 16.

Production Ratio, Percentage of Total Lactating Cows Calving and Total Vitamin A Potency of Queensland Butterfats (Average of 12 Centres).

Seasonal calving is practised to a limited extent in Queensland. The average number of cows calving per month in the 12 centres ranged from 5·2 per cent. in April to 12·4 per cent. in October. Although the percentage cows calving per month is highest in October, the proportion of cows calving to the total number of lactating cows is highest in August.

The lactation curve in Fig. 16 varies uniformly and each successive month is a reflection of the proportion of cows in early and late lactation. The total vitamin A potency curve represents the concentration of the butterfat from cows in these proportions. There is a highly significant positive correlation ($r = 0{\cdot}922$, $P = < 0{\cdot}01$) between the values.

(12) Rainfall Pattern.

The monthly distribution of rainfall is shown in Fig. 17 as an average for the 12 centres.

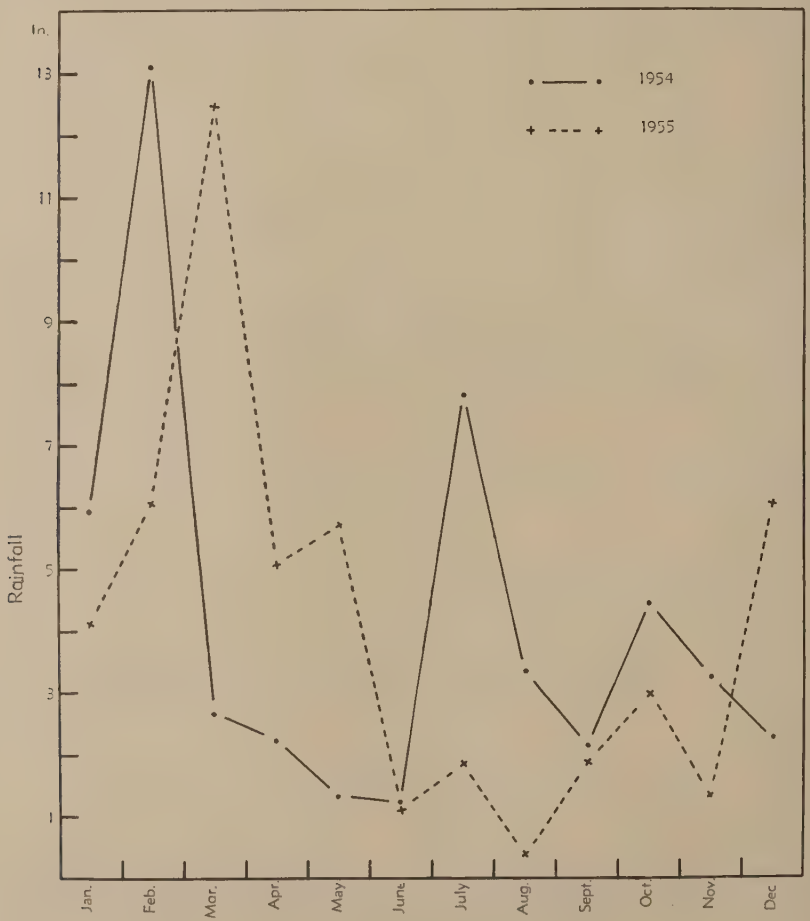


Fig. 17.

Monthly Rainfall Distribution in 1954 and 1955 (Average of 12 Centres).

IV. DISCUSSION.

With grazing throughout the year as practised in Queensland, a uniformly high total vitamin A potency in butterfat might be expected in years of average rainfall. However, marked seasonal trends were found, with maximum values occurring between midwinter and early spring and minimum values between midsummer and early autumn. Similar seasonal trends have been shown for New Zealand butterfats by Barnicoat (1947), McDowell and McDowall (1953) and McGillivray (1956).

Similarly definite seasonal trends are apparent in the vitamin A potency of European and American butterfats; they have been attributed largely to the lower carotene content of winter feed (Lord 1945; Cary 1947; Wiseman and Sheperd 1949; Hibbs, Krauss and Monroe 1949). Higher carotene content of New Zealand winter pastures coincided with higher carotene and vitamin A content in butterfats, and lower carotene content of summer pastures coincided with lower values in butterfats. However, pasture carotene was found on both theoretical and experimental grounds not to be responsible for the fluctuations in New Zealand butterfats (McGillivray 1952; McDowell and McDowall 1953; McGillivray 1956).

In Queensland, the period of maximum rainfall and pasture growth is in summer when the vitamin A potency of butterfats is at a minimum. Limited analyses of pastures (Gartner, unpublished data) showed that carotene content is not a limiting factor to vitamin A potency of Queensland butterfats in years of normal rainfall.

The range between maximum and minimum values in the average monthly carotene values of Queensland butterfats was less than found in New Zealand butterfats by McDowell and McDowall (1953). This was due to the lower maximum values found in Queensland. The range in the vitamin A contents was comparable, the higher maximum values in Queensland being offset by the lower minimum values in New Zealand.

The xanthophyll contents of Queensland butterfats were determined over a period of 18 months. Levels remained relatively constant and were comparable with values determined in New Zealand by McGillivray (1956) over a period of six months. Subsequently, McGillivray (1957) in observations over a period of 10 months showed higher maximum values in August and November.

There were no marked differences in the carotene and vitamin A contents of butterfats from the 12 centres either in 1954 or in 1955. The values for Malanda butterfat were slightly lower in both years than for any other centre. The significance of this difference is not known. The average total vitamin A potency of Queensland butter in both summer and winter was higher than values published for other countries.

The results of this survey are considered in relation to the following data:

Influence of Breed Distribution.—The average breed distribution of the 12 centres was 50 per cent. predominantly Jersey, 47 per cent. predominantly A.I.S., and 3 per cent. mixed breeds. The average proportion of total vitamin A potency in butterfats due to carotene for all centres was 25·2 per cent. in 1954 and 24·7 per cent. in 1955. Farrer *et al.* (1949) found the total potency due to carotene was usually 35–40 per cent. McDowell and McDowall (1953) found it averaged 37 per cent. They attributed this high proportional contribution of carotene to the preponderance of the Jersey breed (about 80 per cent.) in New Zealand dairy herds.

It is characteristic of the Channel Island breeds that in comparison with cows of other breeds they are less efficient converters of ingested carotenoids to vitamin A. This is reflected in higher blood plasma carotenoids (Sutton and Soldner 1945; Wise, Atkeson, Caldwell, Parrish and Hughes 1947) and a greater proportion of total vitamin A potency due to carotene in milk fat (Parrish, Martin, Atkeson and Hughes 1946; Barnicoat 1947; Krukovsky, Whiting and Looski 1950).

The ability of the A.I.S. breed as compared with the Jersey breed to convert carotene to vitamin A was examined. The first year's results showed that the greater the ratio of Jersey to A.I.S. breeds, the greater both the proportion of total vitamin A potency due to carotene and the amount of carotene in butterfat. The centres Malanda and Warwick, containing predominantly A.I.S. cattle, were excluded from the statistical analyses in the second year due to incomplete samples. A lack of significance in that year was possibly due to an absence of values from these two centres. There was no correlation between breeds and the vitamin A or total vitamin A potency of butterfats.

Butterfats from centres containing predominantly Jersey cattle contained a significantly smaller ratio of carotene to total carotenoids as compared with centres containing predominantly A.I.S. cattle. Variations in the ratio of carotene to carotenoids in butterfats have been recorded (Berl and Paterson, 1943; Chanda, Clapham and Owen 1954) but not related to breed differences.

Thus the A.I.S. breed, as compared with the Jersey breed, secretes less carotene and less carotenol pigments in butterfat, indicating more efficient utilisation of ingested carotenoids.

Influence of Production Ratio.—McDowell and McDowall (1953) concluded there was no evidence to connect the changes in carotene and vitamin A content of New Zealand butterfat with the rise in milk and fat yield during

the late-spring to early-summer period, or with the fall in milk and fat yield during the autumn or during periods of drought. McDowell (1956) reviewed the literature on the relationship between stage of lactation and vitamin A potency of butterfats. Various workers found that the vitamin A content of butterfats either rose, fell or remained unaltered towards the end of lactation (i.e., when production is low). McDowell (1956) found that the trend in carotene and vitamin A content in butterfat is seasonal with cows calving in spring and autumn. The evidence regarding increased concentrations during autumn is not as definite when considering an end-of-lactation effect. McGillivray (1956) could not determine from his results on factory butterfats whether the increase in concentration of carotene and vitamin A during autumn was a seasonal trend or an end-of-lactation effect. Subsequently McGillivray (1957) suggested from his findings on individual cows that autumn increases may be due more to an end-of-lactation than to a seasonal effect.

Corrections in butter production data to account for the different number of cows lactating per month were achieved by using the ratio of percentage butter produced in any one month to percentage cows lactating in the same month.

There was a highly significant negative correlation between production ratio and the total vitamin A potency of Queensland butterfats. The influence of production ratio may account for some of the variations in butterfat potencies throughout the year or part of the year.

Influence of Proportion of Cows Calving to the Total Number of Lactating Cows in Any One Month.—When comparing the effect of stage of lactation on the carotene and vitamin A contents of butterfats, New Zealand workers (McDowell and McDowall 1953; McDowell 1956) presented lactation data in the form of percentage cows calving per month.

In any survey, each factory sample of butter is proportionately more representative of cows in early lactation than of those in late lactation, due to the higher average production of the former. The proportion of cows calving to the total number of lactating cows in any one month is therefore a better index of the influence of stage of lactation on the observed total vitamin A potency of butterfat and has been used here.

It is well known that colostrum is high in carotene and vitamin A. McDowell (1956) showed that high values may persist in post-colostral fat for as long as 10–12 days after calving. Thompson and McGillivray (1957) found that concentrations in the milk fat of heifers reached steady levels after about 10–14 days, compared with 6–7 days for cows.

A highly significant positive correlation was found between the proportion of cows calving to the total number of lactating cows in any one month and total vitamin A potency of Queensland butterfats. This could be due partially to the inclusion in butterfat of post-colostral fat of high vitamin A potency.

Influence of Nutrition.—Although the proportion of cows calving to the total number of lactating cows increases from February to July, the production ratio decreases (Fig. 16). As the proportion decreases from August to February, the production ratio increases. This is due to the effect of season on pasture growth, which markedly influences the plane of nutrition in grazing animals.

Influence of Rainfall.—With the exception of Malanda, the annual rainfall for each centre was greater in 1954 and 1955 (Fig. 17) than its mean annual rainfall for either the period 1911–1940 (Bureau of Meteorology, Melbourne) or 1921–1950 (Coaldrake and Bryan 1957). In Malanda 60·11 in. were recorded in 1954, against a long-term average of 66·62 in.

This above-average rainfall resulted in good growth of pasture. It has been shown that butterfat production is related to the plane of nutrition. It has also been shown that marked seasonal trends in the total vitamin A potency of butterfats are inversely related to production. Thus the relationship of rainfall to the vitamin A potency of butterfats is only through its influence on nutrition and production.

Influence of Tocopherol Content and Botanical Composition of Pastures.—The effect of pasture tocopherols on the seasonal trends in New Zealand butterfats was studied by McGillivray (1952). The supplementation of α–tocopherol to cows grazing summer pastures increased both the carotene and the vitamin A content of butterfat to a winter level. It was postulated that low summer vitamin A potencies of New Zealand butterfats may be due to low tocopherol rather than to low carotene levels in pasture and may be associated with the high percentage of clover in summer pasture. McGillivray (1956) found a highly significant correlation between both tocopherol and total vitamin A potency in butterfat.

The apparent seasonal trend in the availability of carotene from New Zealand pastures was further investigated by Worker and McGillivray (1957). Using three sets of monozygotic twins they showed that diets high in white clover (approximately 70 per cent. against approximately 36 per cent.) significantly decreased the vitamin A potency of butterfat. They suggested that this may be due to the low tocopherol content of clover relative to grass, the possibly lower oleic acid content of clover, or some factor or factors present at a time when clover happens to be the dominant pasture species.

A short-term trial was carried out in Queensland (Gartner, unpublished data) to examine the effects of dl–α–tocopheryl acetate supplementation to a set of twin Jersey cows grazing summer pastures. One twin was used as an unsupplemented control. In this limited trial there was no evidence to indicate increased secretion of vitamin A in butterfat by supplementation of 2 g. dl–α–tocopheryl acetate per day. The influence of pasture species, specifically white clover, was not investigated. In contrast with the New Zealand pastures investigated, the proportion of white clover in this predominantly paspalum pasture was negligible at the time of this trial.

V. ACKNOWLEDGEMENTS.

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IODINE VALUE AND SOFTENING POINT AND CHURNING TEMPERATURE OF SOME QUEENSLAND BUTTERFATS

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SUMMARY.

Iodine values and softening points were determined for three years on samples of butter collected fortnightly from 12 centres representing the main dairying districts of Queensland.

Seasonal variations of these two values were markedly uniform on an all-centres basis. Individual centres exhibited less uniform variations between seasons because of differing conditions of feed and animals. Varying conditions of feed and stage of lactation of the milch animal contributed to the seasonal nature of variations between years and among centres.

The all-centres average iodine value was 37.1. Fluctuations throughout the three years ranged from minimum average values of 34.6–35.6 in the January–March quarter to maximum average values of 38.8–39.5 in the July–August months. The iodine value of individual samples ranged from 31.7 to 42.5.

The all-centres average softening point was 33.7 deg. C. Variations throughout the three years ranged from minimum average values of 32.6–33.3 deg. C. in the August–September months to maximum average values of 33.9–34.5 deg. C. during the summer–autumn period of December–May. The softening point of individual samples ranged from 31.0 to 36.4 deg. C.

There was a significant negative correlation between the iodine value and the softening point of butterfat.

The correlation between iodine value and total vitamin A potency was positive and significant.

An examination of cream churning temperatures revealed no relationship between this aspect of butter manufacturing operations and variations in the composition of butterfat as represented by the values of iodine value and softening point. The incidence of body and texture defects in butters suggests that more attention should be given to this relationship.

I. INTRODUCTION.

Butterfat production in Queensland shows marked seasonal trends, with maximum production in late summer (January–March). McDowall (1953) reported that in all States of Australia other than Queensland maximum production is from spring to early summer (September–December). Dairy cattle in Australia are dependent on pasture for the bulk of their feed requirements. Further, lactation periods are arranged generally to coincide with the time of maximum pasture growth. Thus, the level of butterfat production in any of the Australian States is related to the seasonal distribution of rainfall in that State. In Queensland the greater proportion of annual rainfall is during the summer months, whereas the southern States record important winter and spring rainfall.

A further variation in production levels within Queensland occurs as a consequence of widely varying climatic conditions. In some years climatic conditions are characterised by State-wide drought periods and in almost every year dry periods occur in localities in many major dairying districts. The influence of these varying conditions is reflected in varying quality and quantity of pastures and crops available to the grazing animal and the adoption of alleviating farm management practices. These variations in the plane of nutrition also cause changes in the chemical composition of butterfat.

Physical defects in Queensland butters are also of a marked seasonal nature. Although not severe in comparison with overall defects, they are of sufficient magnitude to warrant some form of specialised processing in factories. Rice (1956) reported a serious incidence of these defects in 4 per cent. of all choice grade supplies examined during the period January 1955 to June 1956. The major faults were "mottle," evident during the October-March period, and "open-ravelly," which occurred in the April-June quarter.

McDowall (1953) reviewed investigations into alterations of manufacturing technique to coincide with variations in the composition of butterfat to ensure satisfactory body and texture in butter. He indicated variations in iodine value and variations in softening point of fats as two of the main factors determining the correct cooling techniques and churning temperatures of cream for butter manufacture.

The investigation reported in this paper was undertaken to determine iodine values and softening points in butterfats from 12 dairying centres in Queensland for the years 1954, 1955 and 1956. The degree of variation within years and between years was determined. The possible causes of these variations are discussed.

Cream churning temperatures of each sample were obtained as an indication of the degree of manufacturing control applied.

II. DESCRIPTION OF DAIRYING DISTRICTS.

The dairying industry of Queensland is contained largely in the coastal and subcoastal areas from the border of New South Wales northwards to Rockhampton, the Darling Downs plateau and the Atherton Tableland. Most of the butter production is from the southern portion of the coastal and subcoastal strip.

To ensure that butterfats examined were representative of the varying climatic conditions throughout Queensland, butter samples were obtained

from 12 centres within five districts. These districts are listed below with a brief description of the main agricultural characteristics and dairy management practices:—

(*a*) *Atherton Tableland* is represented by one centre, Malanda. The predominant pasture species of the dairying region are paspalum, kikuyu and molasses grasses, with white clover available in the higher rainfall areas. Some oats and cowcane are used as supplementary green fodders in the dry spring period. Feeding of grain and protein meal is practised on a limited scale. The annual rainfall varies between 40 and 60 in.

(*b*) *Port Curtis* is represented by one centre, Gladstone. The pastures are mainly of native grasses, but there are some stands of Rhodes grass. Lucerne, oats, Sudan grass and millets are grazed during the winter-spring months. No concentrate feeding is practised. The annual rainfall varies between 30 and 40 in.

(*c*) *Burnett–West Moreton* is represented by four centres, Biggenden, Murgon, Kingaroy and Grantham. The predominant pasture species are Rhodes grass, paspalum, green panic and native grasses. Supplementary grazing of Sudan grass, lucerne, maize and millets is practised, but few farmers feed concentrates. The annual rainfall varies between 30 and 40 in.

(*d*) *Wide Bay–East Moreton* is represented by three centres, Gympie, Caboolture and Beaudesert. The pastures are mainly paspalum and kikuyu grasses, with some Rhodes grass and native grasses on the better forest country. Sorghum, Sudan grass, field pea and oats provide the bulk of the supplementary grazing. Lucerne is grazed and concentrates are fed in the Beaudesert area. The annual rainfall varies between 40 and 50 in.

(*e*) *Darling Downs* is represented by three centres, Chinchilla, Toowoomba and Warwick. Except in the Chinchilla area, where native pastures predominate, most of the grazing is on crops. Fodder crops are mainly oats and some early wheat, together with smaller acreages of Sudan grass, lucerne and sorghum. The annual rainfall in this district is relatively low and varies between 20 and 30 in.

III. ANALYTICAL METHODS.

(1) Sampling of Butters.

The method of sampling butters is presented by Gartner (1959), who examined the same samples for carotene and vitamin A.

Data concerning the type and condition of pastures, nature and extent of any general supplementary feeding and cream churning temperatures accompanied each sample.

The limitations of sampling factory butters for analyses because of varying cow numbers have been detailed by McDowell and McDowall (1953). For general survey purposes, however, this method is satisfactory.

Sampling was commenced in January 1954 and concluded in December 1956.

Totals of 715 determinations for iodine value and 760 determinations for softening point were made.

(2) Analyses.

Butterfat samples were prepared by melting butter in an oven at 45 deg. C., decanting the clear butterfat layer into centrifuge tubes, and centrifuging for 2-3 min. at a speed of approximately 2,000 r.p.m. (17 in. diameter). The clear upper portion was retained for analysis.

Iodine value was determined by Wijs' method, using ICl_3 for the preparation of the stock iodine solution as described by Bolton (1928). Samples of 0·45–0·55 g. of butterfat were analysed, using 100 per cent. excess of reagent. The reaction was allowed to proceed in the dark for ½–1 hr. Samples were analysed in duplicate and results agreed within 0·2 units.

Softening point was determined by the method of Barnicoat (1944).

Table 1.

AVERAGE IODINE VALUE AND RANGE OF VALUES OF BUTTERFATS FROM INDIVIDUAL CENTRES.

District.	Centre.	Year.					
		1954.		1955.		1956.	
		Av.	Range.	Av.	Range.	Av.	Range.
Atherton Tableland ..	Malanda ..	38·4	35·4–41·8	*	37·0–41·2	38·2	36·5–40·2
Port Curtis	Gladstone..	35·1	31·7–40·6	37·8	34·2–40·6	36·6	32·0–39·8
Burnett West Moreton	Biggenden	*	31·7–40·0	37·6	32·8–39·9	*	32·2–39·3
	Murgon ..	35·8	33·4–39·5	37·1	34·1–39·6	36·8	33·3–40·7
	Kingaroy ..	36·2	34·2–39·1	37·4	34·1–40·8	37·6	35·2–39·4
	Grantham	36·2	32·9–40·1	37·0	34·8–40·1	37·5	35·4–39·4
Wide Bay–East Moreton	Gympie ..	36·5	33·4–40.2	36·7	33·1–39·5	36·5	32·4–39·4
	Caboolture	36·8	34·0–40·2	37·4	34·4–39·5	36·3	33·5–38·4
	Beaudesert	38·4	33·3–42·2	39·6	36·1–42·5	39·0	35·8–41·5
Darling Downs ..	Chinchilla..	36·3	32·0–40·0	36·9	35·1–38·9	37·9	34·2–40·9
	Toowoomba	36·0	32·8–41·0	36·8	34·2–39·5	36·8	34·9–39·2
	Warwick ..	36·6	32·8–42·3	37·2	34·9–39·0	38·2	35·2–41·9
All Centres	..	36·5	31·7–42·2	37·5	32·8–42·5	37·3	32·0–41·9

* Results for Malanda (1955) and Biggenden (1954 and 1956) are incomplete.

IV. RESULTS.

(1) Iodine Values.

(a) Individual Centres.

Average results and the range of iodine values of samples from individual centres for the three annual periods are listed in Table 1 and Figs. 1–4. Marked seasonal variations in values were apparent, with minimum values in summer months and maximum values in winter months.

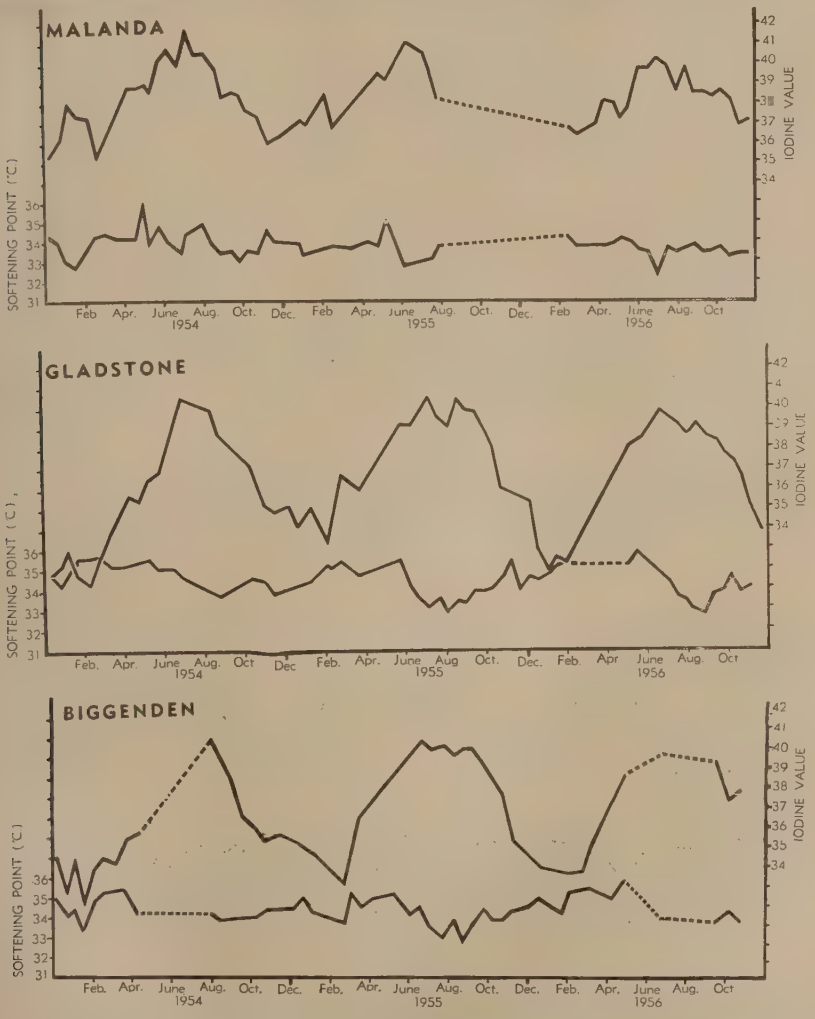

Fig. 1.

Softening Points and Iodine Values for Butterfats from Malanda, Gladstone and Biggenden.

In several centres iodine values showed wide fluctuations between consecutive samples. These variations are illustrated graphically in Figs. 1–4.

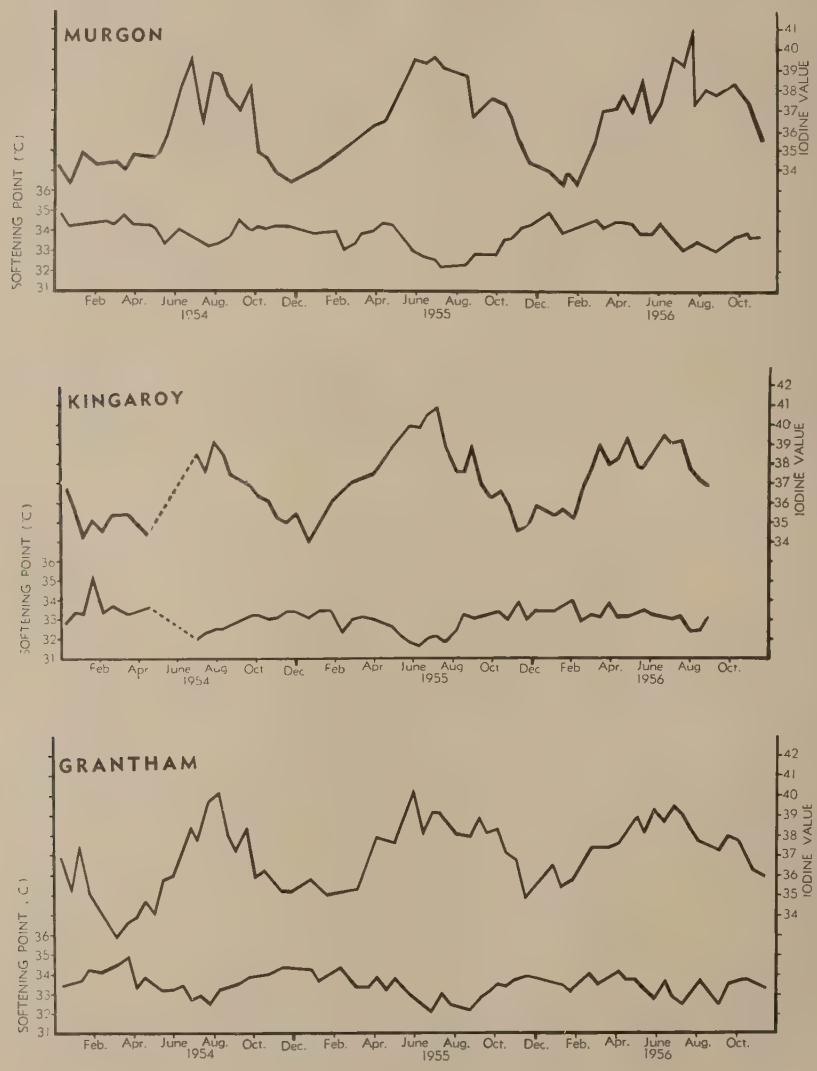

Fig. 2.

Softening Points and Iodine Values for Butterfats from Murgon, Kingaroy and Grantham.

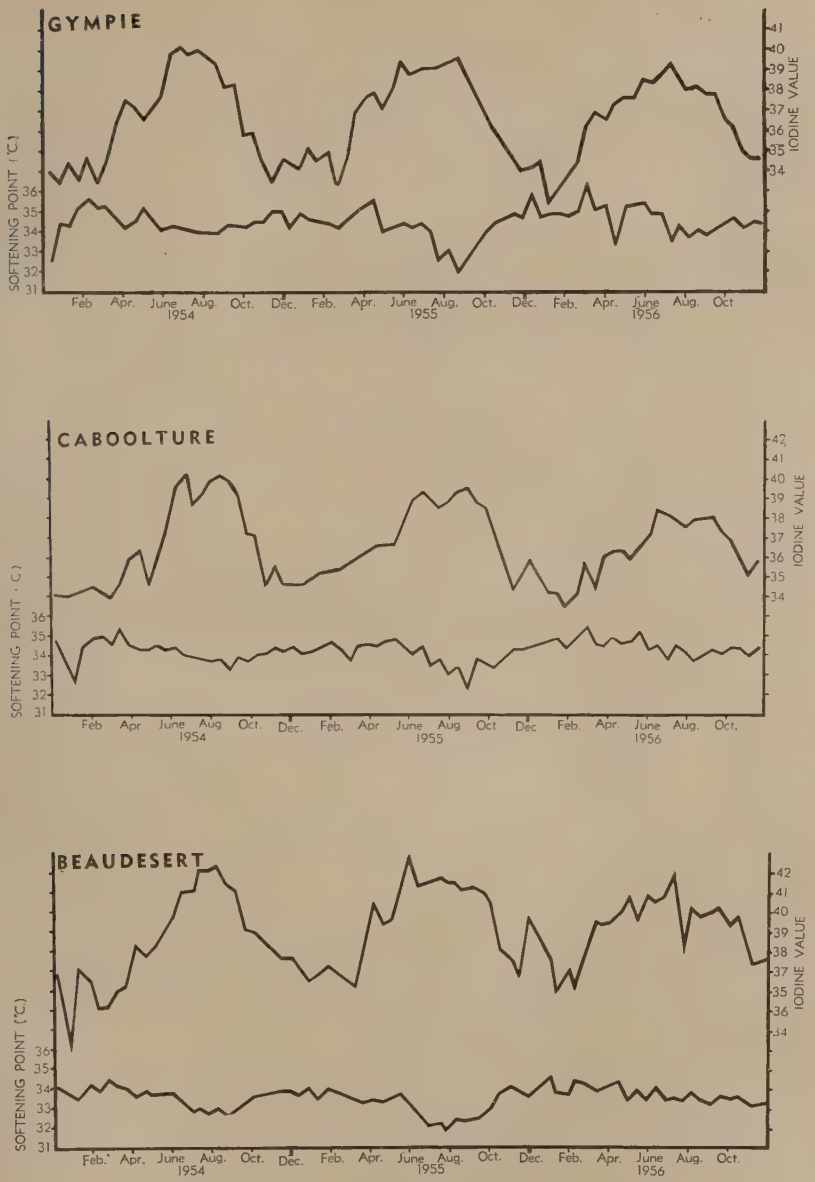

Fig. 3.

Softening Points and Iodine Values for Butterfats from Gympie, Caboolture and Beaudesert.

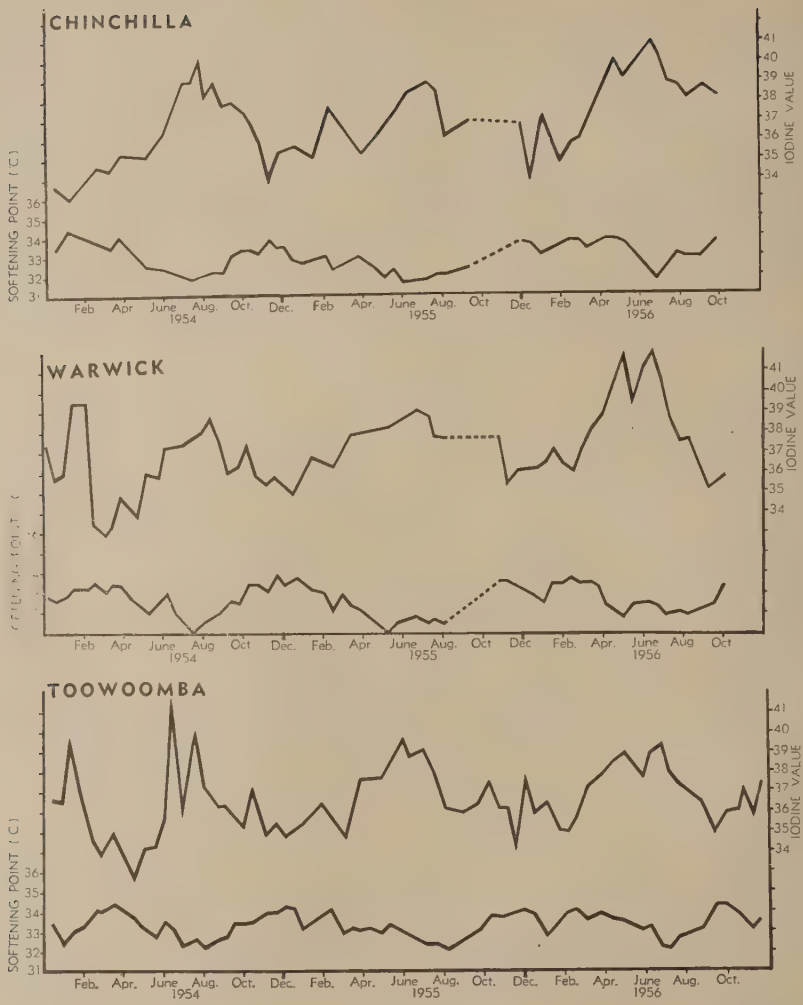

Fig. 4.

Softening Points and Iodine Values for Butterfats from Chinchilla, Warwick and Toowoomba.

(b) All Centres.

Average monthly iodine values of butterfats from all centres are presented in Fig. 5. These results showed a similar yearly seasonal variation, with minimum values occurring in the January–March period and maximum values in the July–August period.

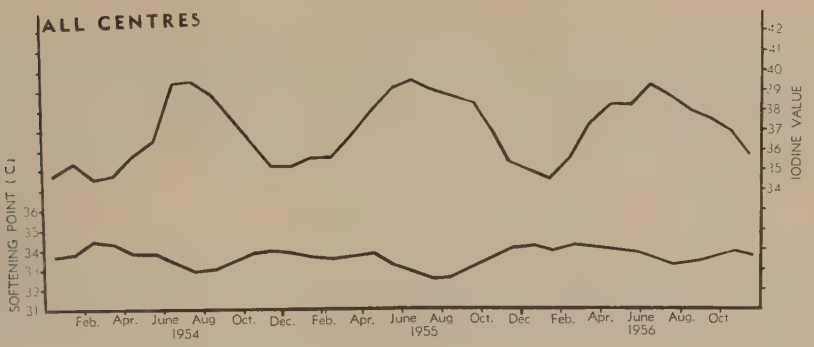

Fig. 5.

Average Softening Points and Iodine Values for Butterfats from All Centres.

(2) Softening Point.

(a) Individual Centres.

Average results and range of softening points of samples from individual centres for the three annual periods are listed in Table 2 and Figs. 1–4. Marked seasonal variations were evident, with minimum values occurring in winter months and maximum values in summer months.

Table 2.

Average Softening Points (°C.) and Range of Values of Butterfats from Individual Centres.

District.	Centre.	Year.					
		1954.		1955.		1956.	
		Av.	Range.	Av.	Range.	Av.	Range.
Atherton Tableland ..	Malanda ..	34·0	32·7–35·9	*	32·8–35·1	33·6	32·4–34·3
Port Curtis	Gladstone..	35·0	33·7–35·7	34·2	32·9–35·4	34·4	32·8–35·9
Burnett–West Moreton	Biggenden	*	33·3–35·4	34·2	32·9–35·2	*	33·8–35·9
	Murgon ..	34·1	33·3–34·9	33·5	32·3–34·4	33·9	33·1–34·9
	Kingaroy ..	33·2	32·0–35·1	32·7	31·8–33·4	33·2	32·3–33·8
	Grantham	33·6	32·5–34·8	33·3	32·3–34·2	33·4	32·5–34·1
Wide Bay-East Moreton	Gympie ..	34·5	32·5–35·7	34·2	32·0–35·4	34·6	33·4–36·4
	Caboolture	34·2	32·7–35·0	34·0	32·4–34·8	34·5	33·7–35·4
	Beaudesert	33·6	32·6–34·5	33·2	31·9–34·1	33·7	33·1–34·6
Darling Downs ..	Chinchilla..	33·0	31·8–34·4	32·5	31·7–33·5	33·3	31·9–33·9
	Toowoomba	33·3	32·2–34·4	33·2	32·0–34·1	33·3	32·1–34·2
	Warwick ..	32·7	31·1–33·9	32·4	31·0–33·7	32·7	31·8–33·4
All Centres	—	33·8	31·1–35·9	33·4	31·0–35·2	33·8	31·8–36·4

* Results for Malanda (1955) and Biggenden (1954 and 1956) are incomplete.

(b) All Centres.

Average monthly values of softening point of butterfat from all centres are presented in Fig. 5. These results showed a similar seasonal variation for each year, with minimum values occurring in the August–September period and maximum values in the December–May period.

(3) Breed Groupings.

As breed of animal can influence the chemical composition of butterfat, results from individual centres were grouped according to the predominant breed. Breed groupings used were "predominantly Jersey" (> 70 per cent. Jersey), "mixed breeds", and "predominantly A.I.S." (> 70 per cent. Australia Illawarra Shorthorn). The results are listed in Table 2.

Table 3.

Average Iodine Values and Softening Points (°C.) of Butterfat from Centres Grouped According to Breed.

Breed.	Percentage Distribution.			Centre.	Iodine Value.			Softening Point.		
	Jersey.	Mixed.	A.I.S.		1954.	1955.	1956.	1954.	1955.	1956.
Jersey ..	90	10	—	Gladstone ..	35·1	37·8	36·6	35·0	34·2	34·4
	85	—	15	Caboolture ..	36·8	37·4	36·3	34·2	34·0	34·5
	70	10	20	Gympie ..	36·5	36·7	36·5	34·5	34·2	34·6
Mixed ..	40	20	40	Biggenden ..	*	37·6	*	*	34·2	*
	40	—	60	Murgon ..	35·8	37·1	36·8	34·1	33·5	33·9
	50	—	50	Kingaroy ..	36·2	37·4	37·6	33·2	32·7	33·2
	40	—	60	Grantham ..	36·2	37·0	37·5	33·6	33·3	33·4
	40	2	58	Toowoomba ..	36·0	36·8	36·8	33·3	33·2	33·3
	47	3	50	Beaudesert ..	38·4	39·6	39·0	33·6	33·2	33·7
A.I.S. ..	25	—	75	Chinchilla ..	36·3	36·9	37·9	33·0	32·5	33·3
	25	—	75	Warwick ..	36·6	37·2	38·2	32·7	32·4	32·7
	35	—	65	Malanda ..	38·4	*	38·2	34·0	*	33·6

* Results for Malanda (1955) and Biggenden (1954 and 1956) are incomplete.

With mixed breeds, iodine values of samples from the Wide Bay–East Moreton district represented by the Beaudesert centre were high in 1954 and 1955.

With A.I.S. breeds, iodine values of samples from the Atherton Tableland district represented by the Malanda centre were high in 1954.

As with iodine values, results from centres were grouped according to the predominant breed (Table 3).

With A.I.S. breeds, softening points of samples from the Atherton Tableland district, represented by the Malanda centre, were high in 1954.

(4) Relationships.

Iodine values and softening points were examined statistically for the three annual periods. In addition, the relationship of iodine values to total vitamin A potency of butterfats (Gartner 1959) was examined. The results are presented in Table 4.

Table 4.

CORRELATION COEFFICIENTS BETWEEN IODINE VALUE AND SOFTENING POINT (°C.) AND IODINE VALUE AND TOTAL VITAMIN A POTENCY OF BUTTERFATS.

Year.	Iodine Value and Softening Point.	Iodine Value and Total Vitamin A Potency.
1954	−0·91**	+0·98**
1955	−0·79**	+0·94**
1956	−0·64*	No vitamin A analyses

** Significant at 1% level.
* Significant at 5% level.

(5) Condition of Feed.

The main characteristics of feeding conditions within districts are given above. Climatic variations between seasons in individual centres, however, resulted in varying qualities of feed during this survey. Where marked, these variations are described in general terms. Pasture and crops were considered to be of good quality if they were still producing leaf and had not matured to the seeding stage.

Initial sampling of butter was commenced at the conclusion of semi-drought conditions in all centres during the late spring/early summer period of 1953. These conditions were relieved by good general rains during January–April in 1954. Feed conditions during 1955 and 1956 were regarded as normal. The variation in climatic conditions in 1954 resulted in pastures maturing and seeding during April–May, compared with the normal March–April period in 1955 and 1956. Towards the end of 1956 semi-drought conditions became manifest.

Marked variations in the condition of feed in different years at various centres were noted as follows:—

In Gladstone in 1955 pasture quality during summer was of a lower standard than during 1954 and 1956.

In Murgon the quality of pasture in summer-autumn differed between 1954 and 1955–56. In 1954, pastures matured and seeded in May, in contrast to the early maturing from January onwards in 1955 and February onwards in 1956.

In Grantham a late summer/autumn flush growth in 1954 contrasted with the summer-maturing pattern of 1955 and 1956.

The late arrival of summer rains on the Darling Downs in 1954 was reflected in good quality feed being available in the Toowoomba and Warwick areas through into the winter months, in contrast with the normal period of November–January. General all-the-year grazing of crops was evident in the Darling Downs district, in contrast with other districts.

(6) Stage of Lactation.

Herd recording information on cows tested in each centre during 1948–1955 was analysed to determine the percentage of cows calving each month. Records of 66,702 lactations from all centres were examined. The results are listed in Table 5.

Table 5.

Percentage of Cows Calving in Any One Month.

Centre.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Malanda	7·5	7·1	6·8	7·2	6·8	8·0	8·7	9·5	9·3	10·7	9·7	8·8
Gladstone	5·5	2·9	2·2	2·3	3·9	6·1	7·2	15·6	15·1	17·3	14·1	7·8
Biggenden	10·5	5·0	5·1	4·0	5·9	6·0	6·5	9·0	10·9	12·4	14·1	10·6
Murgon	8·2	6·2	5·3	5·4	6·3	8·5	8·8	10·1	10·3	10·5	11·0	9·4
Kingaroy	7·9	6·2	6·4	5·7	5·6	6·1	7·9	10·3	11·5	12·7	10·4	9·3
Grantham	5·4	3·9	4·6	5·1	5·7	7·1	11·5	8·7	7·3	14·5	16·6	9·6
Gympie	7·5	5·3	5·2	4·5	4·9	4·7	6·9	11·2	13·1	13·9	12·4	10·4
Caboolture	8·6	6·3	5·6	5·1	5·3	7·2	9·8	10·9	10·7	11·0	10·8	8·7
Beaudesert	8·0	6·7	7·3	6·9	7·1	7·4	7·2	9·4	9·0	11·1	10·7	9·2
Chinchilla	8·3	6·2	5·6	5·2	5·2	6·7	7·7	10·3	10·6	12·9	11·2	10·1
Toowoomba ..	10·1	6·6	7·2	5·6	5·3	6·6	7·9	10·8	10·6	10·4	9·7	9·2
Warwick	7·1	5·7	5·8	5·0	6·1	7·0	10·0	9·5	12·1	11·7	11·1	8·9
All Centres Average	7·9	5·7	5·6	5·2	5·7	6·8	8·3	10·4	10·9	12·4	11·8	9·3

Herds from the Gladstone area exhibited a marked seasonal calving pattern. The most uniform calving pattern was evident in the Malanda and Beaudesert centres.

(7) Cream Churning Temperatures.

The temperatures of cream at churning of butters sampled were averaged for each quarter over the 3-year period and the averages are listed in Table 6. Temperatures tended to be slightly higher in the January–March period and relatively constant for the remaining nine months. Only one centre, Gladstone, evidenced any wide variation between quarters. This centre also exhibited the highest temperatures.

Table 6.

AVERAGE CREAM CHURNING TEMPERATURES (°F.) OF BUTTER SAMPLES FOR 1954–1956 CALCULATED QUARTERLY.

Centre.	January–March.	April–June.	July–September.	October–December.
Malanda	47	46	45	46
Gladstone	54	55	52	53
Biggenden	46	47	47	47
Murgon	49	49	48	48
Kingaroy	51	49	49	51
Grantham	48	47	46	48
Gympie	46	46	46	46
Caboolture	47	48	47	47
Beaudesert ..	46	47	47	47
Chinchilla	46	47	46	46
Toowoomba ..	45	45	45	44
Warwick	46	46	45	46
Average	47·7 (42–58)*	47·3 (42–56)*	47·0 (38–56)*	47·2 (40–58)*

* Values in brackets represent the extremes for all centres.

There was an extremely wide range of individual churning temperatures within quarters.

V. DISCUSSION.

(1) General.

There was a uniform seasonal variation in iodine values and softening points of the butterfats. The monthly average iodine values and softening points from all centres showed similar seasonal variations in the three years examined. The variations in these values for individual centres was less uniform.

The values obtained in this survey were in agreement with those found by Wiley and Loftus-Hills (1949) in their examination of Australian butterfats. Values were of a comparable nature to the constants of New Zealand butterfats reported by Cox and McDowall (1948), McDowell (1953), Mayhead and Barnicoat (1956) and McGillivray (1956), although Queensland values covered a slightly wider range. Both Australia and New Zealand, in contrast with dairying countries in the northern hemisphere, rely on continuous grazing for milch animals without recourse to stall feeding during winter months. It might be expected, therefore, that seasonal variations in values for constants in butterfat would be similar in Australia and New Zealand.

A relationship between iodine value and softening point, significant at the 1 per cent. level, was obtained in two of the three years. Such a relationship was explained by Hilditch (1940) in terms of the oleic acid content of butterfat. McDowall (1953), however, suggested that differences in the combination of fatty acids to form the glycerides can compensate for the tendency of oleic acid glycerides to be oily in nature.

(2) Influence of Condition of Feed on Iodine Values.

The relationship of oleic acid content of butterfat to iodine value has been reported by several workers. Hilditch (1940) reported that variations in the iodine values of milk fats were due to changes in the oleic acid content. Hansen and Shorland (1952) concluded that, although the iodine value of butterfat was not directly proportional to the C18 unsaturated acids of fat, it was an indication of the amount of these acids. McDowell (1953) and Wood and Haab (1957) analysed samples of butterfat by spectrophotometric methods and demonstrated the direct relationship of oleic acid content to iodine value.

The effect of chemical composition of feed on the unsaturation of fatty acids of butterfat has been established. Glascock (1954) indicated that oleic acid is not synthesised to any appreciable extent in the udder but is derived directly from the diet. This conclusion was supported by Mayhead and Barnicoat (1956). Shorland (1944) reported a high proportion of oleic acid in the fat from pastures. He found that the fat content of pastures was characterised by a high content of C16–18 unsaturated acids (82·9 per cent.), of which oleic acid was predominant (76·5 per cent.). Worker and McGillivray (1957) showed that the botanical composition of pasture influenced the unsaturated fatty acid content of the diet. They reported that milk fat from clover-fed cows had a lower iodine value than that from cows fed on ryegrass.

McGillivray (1952) advanced the theory that a second factor, the tocopherol content of the pasture, is associated with the seasonal variation of unsaturation of fatty acids in butterfat.

No differential unsaturated fatty acid analyses have been reported for Queensland pastures. However, it seems valid to assume that a similar dietary contribution from pastures exists in Queensland.

As the breed and lactation pattern of milch animals within centres does not alter materially within a short term, variations of the condition of feed between years should be reflected in the iodine value of fats. Variations of this nature were found in this survey.

In Gladstone, minimum iodine values which occurred during January–March were at their highest level in 1955. The quantity and the quality of feed during this year were both of a lower standard than in 1954 and 1956. In Murgon, low iodine values continued from January until June in 1954, in contrast with the minimum period of November–February in 1955 and January–March in 1956. Good quality pasture was available until winter in 1954 in contrast with the more normal pattern of summer maturing of pastures in 1955 and 1956. Minimum iodine values from Grantham in 1954 coincided with the autumn flush pasture growth and were of a lower degree than minimum values in 1955 and 1956. A similar variation occurred in 1954 in samples from Warwick and Toowoomba. Seasonal trends were less uniform in the Darling Downs district than in other centres. The comparatively extensive use of grazing crops such as oats, Sudan grass and wheat in this district could explain these variations.

Possible explanations of the differences in values between consecutive samples from certain centres (Toowoomba, Warwick, Gympie) are (1) the variation in condition of feed resulting from local weather conditions, and (2) the influence of these weather variations on the metabolism of the animal. McGillivray (1956) found evidence of weather variations causing fluctuations of 1-2 units in iodine values between consecutive samples. Mayhead and Barnicoat (1956) also reported daily variations in iodine values of samples from the small herd in their investigations.

Iodine values generally remained at a low level until the April–May period in 1954, in contrast with the February–March period in 1955 and 1956. This possibly resulted from better quality feed being available through to the late summer months in 1954.

The variations within centres between seasons in different years in this survey indicated the influence of the condition of feed on the degree of unsaturation of fatty acids in butterfat.

(3) Influence of Stage of Lactation on Iodine Value.

Schlag (1926) reported a fall in iodine values of butterfat during the first three months of lactation, followed by a steady rise for the remaining seven months. McDowall (1953) reported that other European workers confirmed this influence of lactation on iodine value.

Maximum average annual values and the widest ranges of iodine values were found in samples from the Malanda and Beaudesert centres (Table 1). It was in these centres that the percentage of cows calving monthly was most uniform (Table 5). This indicated that the proportion of cows "in milk" over three months was greatest in these centres and also that there was a more uniform distribution of varying stages of lactation among herds.

A comparison of the influence of breed on iodine values (Table 3) for the six centres comprising mixed breeds showed the Beaudesert centre to have higher than average values in all three years.

The seasonal nature of calving was most marked for Gladstone. In the August–November period 62·1 per cent. of cows calved, in contrast with the all-centres average of 45·5 per cent. Samples from this centre exhibited extreme seasonal fluctuations in iodine values.

These results suggest that the influence of stage of lactation on iodine value is strong. However, because of the interaction of feed, breed and stage of lactation, no specific conclusions on this point can be drawn.

(4) Relationship of Iodine Value and Total Vitamin A Potency.

McGillivray (1956) reported a correlation of +0·459 between iodine value and total vitamin A potency of butterfat. McDowell and McDowall (1953) showed that in New Zealand commercial butterfats a parallel between vitamin A potencies and iodine values exists. In Queensland a correlation of a high order—viz., +0·98 in 1954 and +0·94 in 1955, both significant at the 1 per cent. level—was obtained.

(5) Cream Churning Temperatures and Butter Defects.

The relationship of iodine values and softening points of butterfat to body and texture of butter has been examined extensively and references were reported by McDowall (1953). While the rate and degree of cooling, time of holding of cream and the temperature and technique of butter washing all determine the body and texture of butter, temperature of cream at churning is a reliable guide in relating manufacturing conditions to the varying chemical composition of butterfat. The churning temperature records obtained in this survey indicate only minor variations from average churning temperatures during the year. This absence of control was reported by Wiley and Loftus-Hills (1949). The average cream temperature range of 47·7 to 47·0 deg. F. among quarters was extremely narrow when related to recommended levels for Queensland conditions of 42–46 deg. F. during summer months and 46–50 deg. F. during winter months. The wide range of individual churning temperatures, 38 to 58 deg. F., during the year indicated unsatisfactory control of temperature.

Mottle defects are evident in Queensland butters during the spring–summer period. These occur because the degree of working during manufacture is insufficient to incorporate evenly the salt and moisture constituents. As the normal practice is to work butter until it is soft, the conclusion to be drawn is that with butter in which this defect occurs grains were not in the correct physical state to permit optimum working conditions. Several

European workers have established a relationship between iodine values and texture faults. Dolby (1949) drew attention to the relationship between iodine value and the hardness of butter. The absence of seasonal variations in cream churning temperatures of butters examined in this survey suggest that due recognition had not been accorded to variations in iodine values of butterfat.

The texture faults "open-ravelly" occur in Queensland butters during the April–June period. Butterfat during this period was characterised by a rapid rise in iodine values, while softening points exhibited only a slight decrease. Corrective manufacturing methods in this instance should be directed to alterations in the rate and degree of cooling rather than in the cream churning temperatures. Information on cooling techniques was not available. References to similar circumstances in New Zealand butterfats were reported by McDowall (1953).

From information obtained in this survey it is concluded that a more correct application of cream churning temperatures in relation to variations in the iodine values of butterfats would assist in minimising the incidence of body and texture defects.

VI. ACKNOWLEDGEMENTS.

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THE COPPER CONTENT OF SOME QUEENSLAND BUTTERS

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SUMMARY.

The copper content of over 250 samples of commercial butter representing churnings from 30 factories ranged from 0.05 to 0.70 p.p.m.

Comparison of butters from a factory with untinned copper equipment with those from a factory with stainless steel equipment showed a marked incidence of high copper content in the former and little evidence of copper in the latter.

An examination of copper contamination on the farm showed that the first milk through the milking machine was heavily charged with copper in one plant when bare brass equipment was used, while no such contamination was evident in a plant with stainless steel and glass equipment.

Some suggestions for reducing copper contamination in milk, cream and butter are offered.

I. INTRODUCTION.

It is well known that minute amounts of copper may accelerate the oxidation of fat and thus have a detrimental effect on the keeping quality of various dairy products. In the manufacture of butter, copper contamination of the cream may come from untinned copper and brass equipment in the factory. Cream may also have an increased copper content due to milk on the farm acquiring copper from untinned brass pipelines and other equipment. Increased use of stainless steel on the farm and in factories has to some extent reduced contamination by copper, but in many factories the problem still remains. This paper reports briefly the results of a survey of copper contamination of milk, cream and butter from some Queensland farms and factories.

II. METHODS.

Samples of butter were taken from boxes on the grading floor using stainless steel tryers. The plugs of butter were stored in acid-washed bottles.

Cream and milk samples were collected in acid-washed bottles.

Copper determinations were done by the wet-ashing method of McDowell (1947). Results are given to the nearest 0·05 p.p.m.

III. RESULTS.

Table 1 shows the distribution of results on 240 samples of butter.

Table 1.

Distribution of Results on 240 Samples of Butter.

Copper (p.p.m.).	No. of Samples.
0·05	10
0·10	56
0·15	63
0·20	46
0·25	22
0·30	13
0·35	9
0·40–0·70	21

Results on a further 14 samples of butter from one factory (A) with some bare copper equipment are given in Table 2 and are compared with six samples obtained from another factory (B) in which all the equipment was stainless steel.

Table 2.

Comparison of Results from Two Factories.

Copper (p.p.m.).	Number of Samples.	
	Factory A.	Factory B.
0·05	..	6
0·10	..	..
0·15	1	..
0·20	1	..
0·25	3	..
0·30	2	..
0·35	3	..
0·40–0·70	4	..

The copper content of a series of cream samples from factory A is shown in Table 3.

Table 3.

RESULTS OF FACTORY SURVEY.

Points of Sampling.	Copper (p.p.m.).	
	First Flow.	Later Flow.
Raw cream in neutralising vat	0·30	..
Raw cream neutralised	1·3	0·35
Pasteurised cream from balance tank ..	1·7	0·40
Pasteurised cream entering holding vat ..	1·9	..
Butter	..	0·45

Table 4 gives the results for two series of milk samples taken on farms, one (D) from a milking machine in bad condition with some bare brass showing on equipment, the other (E) from a new stainless steel and glass plant.

Table 4.

COPPER CONTENT OF MILK (p.p.m.).

Points of Sampling.	Plant D.	Plant E.
Milk direct from cows	0·15	0·15
First milk from releaser	2·0	0·20
Later milk from releaser	0·15	0·15
First milk into can	0·6	0·20
First can full	0·45	0·15

IV. DISCUSSION.

The results show that the incidence of copper contamination of butter in Queensland factories is most variable and in many instances exceeds the usually accepted limit of 0·15 p.p.m. Kruisheer *et al.* (1943) suggested that this limit might be too high. More than 45 per cent. of the butters examined in the present work have a copper content greater than 0·15 p.p.m.; consequently, if the standard taken were less than 0·15 p.p.m., approximately 75 per cent. of the samples would fall outside the desired range.

It would seem from the results that the standard of less than 0·15 p.p.m. was attainable in 25 per cent. of the samples and it is recommended that this standard be adopted for advisory purposes.

The results show that it is possible to pinpoint sources of contamination on farms and in factories.

On the farm, the milking machine appears to be the most important source of copper, but the vat, cooler and cans are also important sources.

Tables 3 and 4 give an indication of the amount of metallic contamination which can come from pumps, pipelines, vats, pasteurisers and other equipment in the factory.

The results have demonstrated the value of stainless steel in reducing contamination by copper. It is apparent that copper equipment should at least be kept well tinned and that it should, as circumstances permit, be replaced by stainless steel. As it has been shown that the first flow of cream through a plant may be heavily contaminated with copper, the first cream through the unit should be diverted to a lower grade. In the case of milk, the first flow through the plant can be similarly diverted and used for stock food.

In the butter factory, churning the first cream through the plant separately would assist in reducing the copper content of subsequent churnings.

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SOIL SURVEY OF COOLUM FIELD STATION. SOUTH-EASTERN QUEENSLAND

By R. J. TALBOT, B.Sc., and P. D. ROSSITER (formerly of Chemical Laboratory, Division of Plant Industry).

SUMMARY.

An area typical of much of the wallum country which extends along a large part of the south-eastern coast of Queensland was surveyed. The soils mapped have been divided into three great soil groups—Lateritic–Podzolic Soils; Aeolian and Marine Alluvial Sands; and Acid Swamp Soils.

The geological complexity of the area complicates any endeavour to interpret the genesis of the soil groups encountered.

All soils are chemically infertile and with the exception of the acid swamp soils possess poor moisture-retaining properties.

I. INTRODUCTION.

The Coolum Field Station of the Queensland Department of Agriculture and Stock was established in 1952 in an area typical of much of the wallum country of south-eastern Queensland.

"Wallum" is an aboriginal word for *Banksia serratifolia*, a tree commonly known as bottle-brush. Conventional usage has obscured the original meaning and the term "wallum" is now used loosely in reference to a long, relatively narrow strip of infertile lowlying coastal country which extends in an almost unbroken line from the southern border of Queensland to Bundaberg and intermittently further north.

Various species of *Banksia*, including *B. serratifolia*, constitute a distinct plant society on portions of the wallum, but it is not the dominant society. Large areas of poorly drained soils are characterised by dense stands of tea-tree, of which *Melaleuca leucadendra* is the most important.

The surveyed area is approximately 2,000 acres in extent and consists of Portions 470 and 610, Parish of Maroochy, County of Canning, as shown in the locality map (Fig. 1). The survey (10 chain grid) was frequently interrupted by adverse weather and the main time spent in the field occupied part of September 1953 and parts of December 1954 and January 1955. Accurate delineation of soil boundaries was aimed at, but the uneven nature of the surface of drainage lines made estimation of distances across these areas particularly difficult.

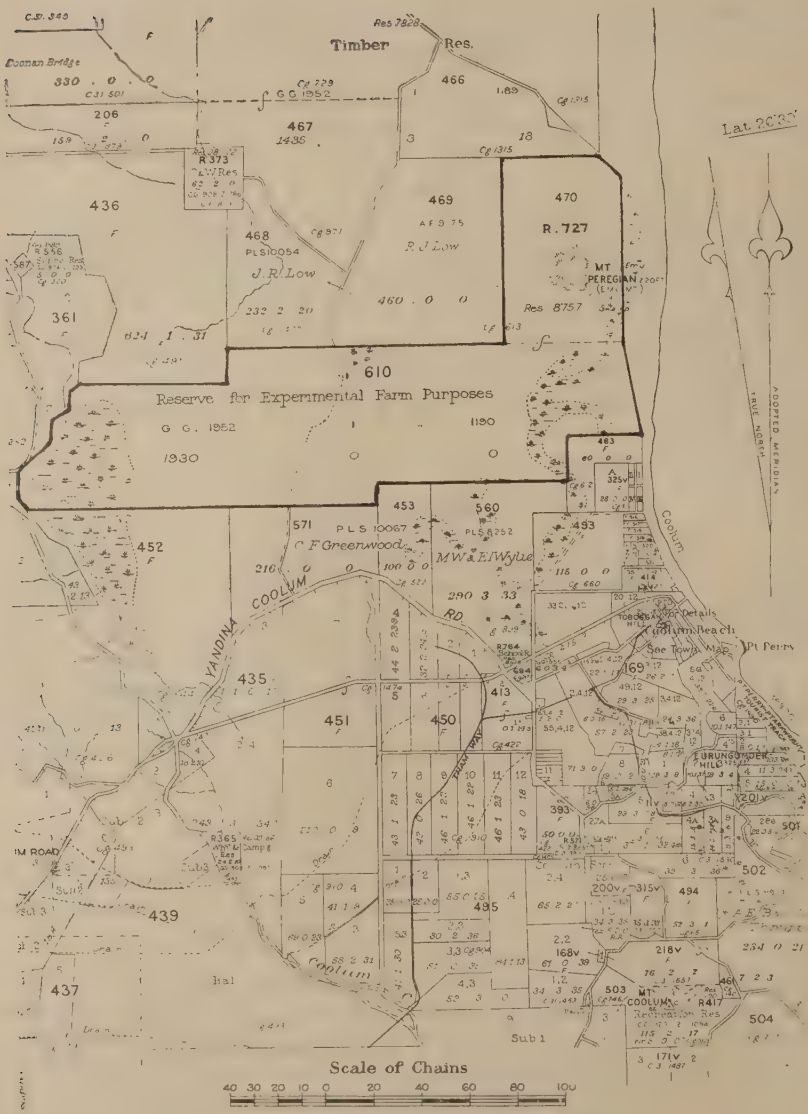

Fig. 1.

Locality Map Showing Coolum Field Station.

II. TOPOGRAPHY.

The dominant topographical feature of the area surveyed is Mt. Peregian (Emu Mt.) a trachy-rhyolite plug rising to a height of 220 ft. in the south-eastern corner of Portion 470. Dissected open sclerophyll forest ridges form the western boundary of Portion 470 and the western half of the northern boundary of Portion 610. Portion 610 is bisected by one of these ridges which runs north-west to south-east, and on the southern point of which is found a small outcrop of a "granophyric aplite." To the west, Portion 610 is bounded by the swampy foothills of Middle Ridge, often known locally as the Valdora Range. The country to the south of the forest ridges mentioned above is lowlying and consists of numerous small wind-blown sand dunes which are slightly more elevated than the flat sandy heath. Crossing the dune and heath sands to form an intricate pattern are the extensive hummocky-surfaced drainage lines which in a large part take the form of tea-tree swamps.

III. GEOLOGY.

The geology of the Coolum area is complex. Members of the Science Students Association of the University of Queensland have studied the area from time to time and their observations have confirmed, and elaborated on, the surveys of the area carried out by Jensen (1906) and Richards (1938). The basal rocks of the area are thought to be the Mesozoic freshwater sediments (Richards 1938) and it seems likely that the "relict sandy lateritic soils" (Hubble 1954) of the open sclerophyll forest ridges, mapped at the series level as Peregian Loamy Sand and Maroochy Loamy Sand, were formed from these sediments.

The Mesozoic sediments have been intruded by numerous igneous bodies, one of which is a coarse-grained aplite, or to use Jensen's phrase, "granophyric aplite." This rock is exposed on the cliff face at Pt. Perry, just south of Coolum Beach, and the rocky outcrop mapped on the ridge bisecting Portion 610 is considered to be part of the same intrusion.

Mt. Peregian is a tertiary volcanic plug which probably formed an island (Richards 1938) until the last fall in sea level. The rock is a fine-grained trachy-rhyolite containing sanadrine, hornblende and some biotite (Daniels 1950).

The lowlying dunes and heath were below sea level until the last emergence and the parent material of soil types found here would certainly seem to be of marine origin. At depths of between 2 ft. and 3 ft. 6 in. below most of the heath sand is encountered a black to brownish-black indurated layer of variable thickness. It is impenetrable at times to a soil auger but can be broken with difficulty by using a mattock or a pick. When lumps of this material are removed they crumble readily to give the texture of a loamy sand.

In a pit dug on Portion 610 the indurated layer was found between 2 ft. and 5 ft. Entry of water into the pit prevented investigation at this time to greater depths.

IV. CLIMATE.

The climate is best described as humid subtropical. The average annual rainfall of 69 in. shows a decided summer incidence. Table 1 gives the rainfall distribution for the years 1953-1957.

Table 1.

RAINFALL AT COOLUM FIELD STATION, 1953–1957, IN INCHES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1953	11·96	11·42	6·34	5·37	1·82	·34	·43	4·06	2·33	5·66	6·97	2·55	59·19
1954	5·24	20·67	3·87	2·53	5·53	1·54	18·07	4·70	3·10	5·94	3·42	2·34	75·95
1955	1·59	7·41	19·95	8·21	11·09	3·14	2·10	nil	2·25	4·42	1·72	7·18	69·06
1956	5·12	15·31	21·56	4·19	6·39	3·52	4·31	·27	1·85	1·84	5·38	12·26	82·00
1957	7·65	3·59	4·74	·14	·18	2·30	8·42	3·29	·13	1·92	2·04	·69	35·09
1958	4·99	11·07	9·80	22·29	3·27	22·62	nil	1·32	·99	·72	3·24	4·15	84·46

V. VEGETATION.

Vegetation is fairly closely correlated with soil type, which in turn seems to be largely dependent on topography.

The dominant species on Peregian Loamy Sand and Maroochy Loamy Sand are scribbly gum (*Eucalyptus micrantha*), red bloodwood (*E. intermedia*) and a stringybark (*E. phaeotricha*), with occasional tea-tree (*Melaleuca leucandendra*) and grasstree (*Xanthorrhoea hastile*). There is generally a fairly good ground cover of kangaroo grass (*Themeda australis*).

Banksia serratifolia, previously known as *B. aemula,* is the dominant species of the wind-blown dune sands (Wallum Sand). This tree proved to be an excellent indicator of soil type. On only one occasion was it found growing where the black indurated sand horizon was encountered at a depth of less than 3 ft. 6 in. Grasstree is sometimes co-dominant with *B. serratifolia* in the dune sands, while odd tea-trees are also present. A sparse ground cover of kangaroo grass may or may not be found.

The typical vegetation of the heath is the small banksia (*Banksia robur*) and grasstree co-dominant, with occasional *Banksia oblongifolia.* A wide range of proteaceous plants and numerous sedges are found in smaller quantities. Areas of heath having a peaty surface on occasions support a dense stand of the proteaceous shrub *Hakea gibbosa* and the tea-tree *Melaleuca nodosa.*

Drainage lines are characterised by the dominance of the tall-growing and closely packed tea-tree (*M. leucandendra*). The tea-trees *Melaleuca nodosa* and *Callistemon pachyphyllus,* the proteaceous shrubs *Hakea gibbosa* and *Petrophila shirleyae* and the she-oak or forest oak (*Casuarina littoralis*) are frequently found in association with *Melaleuca leucandendra.*

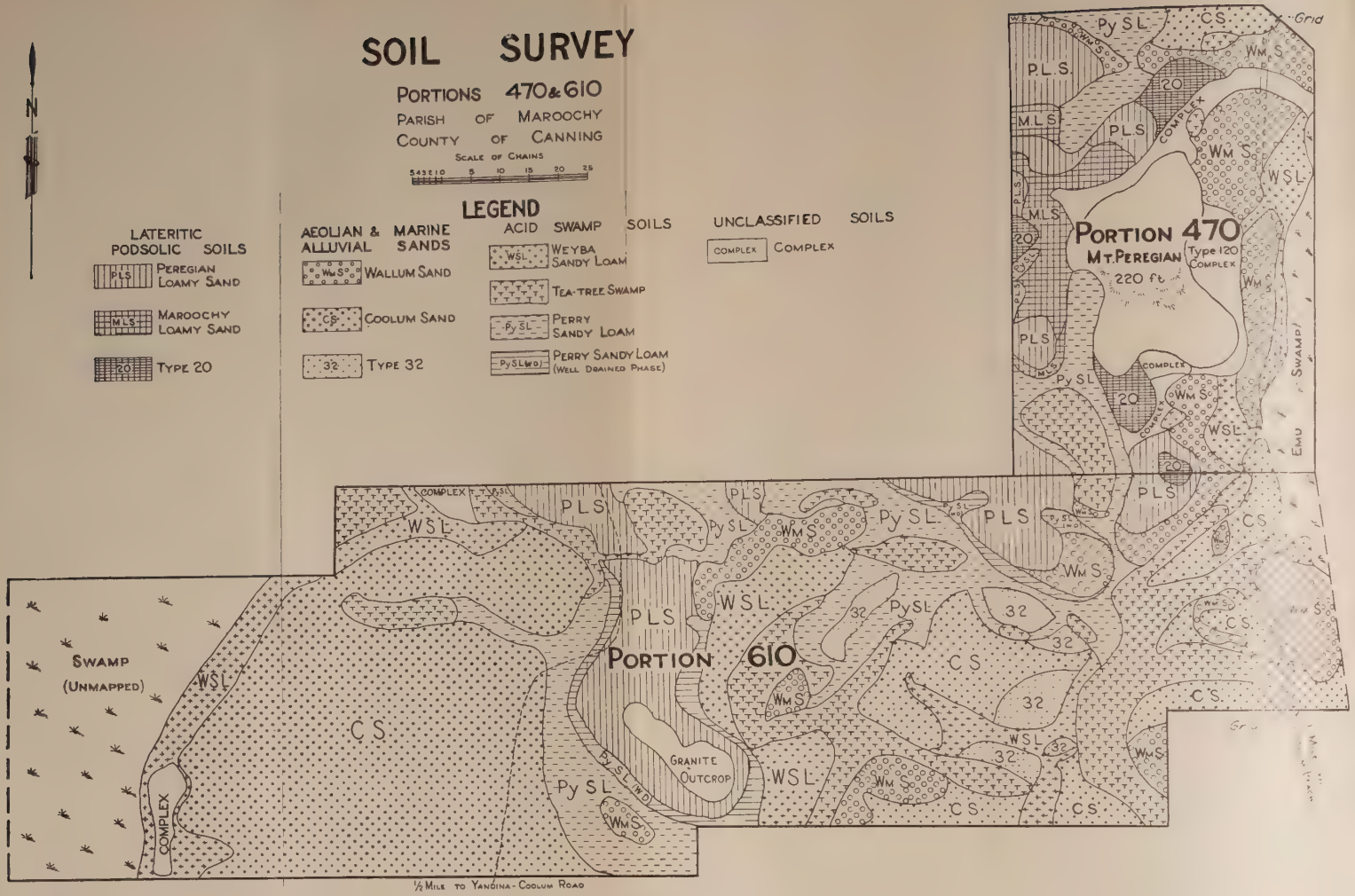
SOIL SURVEY
PORTIONS 470 & 610
PARISH OF MAROOCHY
COUNTY OF CANNING
SCALE OF CHAINS
5 4 3 2 1 0 5 10 15 20 25
N
LEGEND
LATERITIC PODSOLIC SOILS
PLS PEREGIAN LOAMY SAND
MLS MAROOCHY LOAMY SAND
20 TYPE 20
AEOLIAN & MARINE ALLUVIAL SANDS
WmS WALLUM SAND
CS COOLUM SAND
32 TYPE 32
ACID SWAMP SOILS
WSL WEYBA SANDY LOAM
TEA-TREE SWAMP
PySL PERRY SANDY LOAM
PySL(WD) PERRY SANDY LOAM (WELL DRAINED PHASE)
UNCLASSIFIED SOILS
COMPLEX COMPLEX
PORTION 470
MT. PEREGIAN
Type 120 COMPLEX
220 ft
PORTION 610
SWAMP (UNMAPPED)
GRANITE OUTCROP
EMU SWAMP
½ MILE TO YANDINA - COOLUM ROAD

Fig. 2.

VI. SOIL TYPES.

The soils of the surveyed area fall into three distinct great soil groups. These are:—

1. *Lateritic Podsolic soils*—
   - (*a*) Type 100—Peregian Loamy Sand.
   - (*b*) Type 10S—Maroochy Loamy Sand.
   - (*c*) Type 20—Unnamed complex.
2. *Aeolian and Marine Alluvial sands*—
   - (*a*) Type 30—Wallum Sand.
   - (*b*) Type 31—Coolum Sand.
   - (*c*) Type 32—Unnamed.
3. *Acid Swamp soils*—
   - (*a*) Type 40—Weyba Peaty Sand.
   - (*b*) Type 110—Perry Sandy Loam—non-peaty type—peaty type.
   - (*c*) Tea-tree swamps.

Several small areas of miscellaneous soil types have not been grouped. The distribution of the soil types is shown in the inserted map.

VII. GENESIS OF SOILS.

The complex geology of the area makes it very difficult to interpret the genesis of the various soil groups encountered.

(1) Group 1.

The Lateritic Podsolic soils have already been described by Hubble (1954) as "Relict Sandy Lateritic soils" and considered to be formed from Mesozoic sandstones. No evidence was found at Coolum to contradict this conclusion. The extremely sandy nature of the surface horizons (84 per cent. sand) may suggest that the original laterite was eroded away to the depth of the indurated horizon and in some cases to the mottled horizon, and that the soils now found were developed from some material deposited on top of the eroded laterite. Granite outcrops do occur in Portion 610 and Portion 469 nearby, and while it is possible to think of this as a source of parent material, the fact that an auger was put down to a depth of 2 ft. 6 in. without encountering bedrock, not more than 30 yd. north of the granite outcrop on Portion 610, indicates that the granite has had very little influence on soil formation in the area. Probably marine sands have been transported by wind onto some of the areas of "Relict Sandy Lateritic soils" subsequent to the formation of the original profile, for the percentage of fine sand decreases with depth down to the B_1 horizon. Although there is no field evidence of podsolisation in the form of an ashy A_2 horizon, chemical analysis with respect to exchangeable cations does suggest slight podsolisation. The decrease in the percentage of clay in the A_2 horizon is also characteristic of podsolisation.

The Peregian Loamy Sand has been divided into two phases. One phase has a distinct horizon of ironstone pebbles very weakly cemented. This horizon, which is 2–4 in. thick, is located between the yellowish brown sandy loam to sandy clay B_1 horizon and the mottled B_2 horizon. It has been designated the nodular phase. It contains both nodules and concretions.

The significance of the nodular horizon from the point of view of soil genesis is difficult to interpret. An Army contour map does not show any marked difference in elevation between areas where the concretionary horizon is present and areas where it is absent. However, it is noticeable that the areas having a nodular and concretionary horizon are located along the western boundary of Portion 470 and in close proximity to Mt. Peregian. One possibility is that this portion of the area was previously at a lower elevation than at present, and the nodular horizon was formed there under the influence of a fluctuating water-table. When Mt. Peregian was extruded the whole profile was raised to its present level, and since that time there would have been no additions to the nodular horizon.

(2) Group 2.

The genesis of soils of group 2 would appear to be fairly straightforward. The Wallum Sands are wind-blown sand dunes of recent origin which stand higher than the surrounding heath sands by 2–10 ft. There is no profile differentiation to a depth of 3 ft. 6 in. Frequently the profile to a depth of 6 ft. is of undifferentiated sand but the depth of 3 ft. 6 in. was chosen arbitrarily in order to separate Wallum Sand from Coolum Sand. The "carbonaceous sandstone" layer was encountered at 77 in. under one area of Wallum Sand in Portion 610. It probably underlies all Wallum Sands, its depth from the surface depending upon the height of the dune relative to the adjacent heath areas.

The Wallum Sand is well drained and invariably supports the tall-growing banksia as the dominant species.

The direction of the long axis of these dunes varies throughout the area and has probably been influenced by both the direction of the prevailing winds and the position of the more elevated forest areas. Generally speaking, the long axis is parallel to the direction of the foothills of the forest areas. The dunes furthest removed from the forest areas have been wholly or partly dissected.

The Coolum Sand is lower in elevation than the Wallum Sand and the surface material is probably a mixture of both aeolian and marine alluvial sand. These horizons overlie black to very dark brown "carbonaceous sandstone," which is massive and very hard *in situ* but crumbles readily when pressed between the fingers. The thickness of this material was found by hydrologists of the Irrigation and Water Supply Commission to be 4 ft. 6 in. on Portion 610 commencing at a depth of 2 ft.

On Portion 470 the "carbonaceous sandstone" was found at a depth of 1 ft. and was 8 ft. in thickness. Below this was a brown sand which extended to approximately 20 ft., at which depth a white to grey gley clay was encountered. On Portion 493 nearby it occurred at 34 in. and was 26 in. through; at 60 in. a yellow brown sand was encountered.

A cursory comparison of the profile of the Coolum Sand and the Ground Water Podsol as described by Hubble may suggest that the Coolum Sand is a Ground Water Podsol in which the white "fragipan" has not been formed. Such is not the case. The "carbonaceous sandstone" at Coolum is considered to be a geological layer, possibly the remants of marine or freshwater swamps. Young, speaking of the "carbonaceous standstone" (which he calls black sandstone) associated with wallum soils, stated: "This black sandstone of the true wallum soil does not occur elsewhere on the coastal plain but it is interesting to note that it is to be found on Fraser Island and may possibly be a relic of a coastal uplift. On Fraser Island it is exposed in the sand-cliffs on the eastern side of the island and at sea-level on the west, and forms the bed of the freshwater lakes."

It would seem then that the swamps were covered with marine sand during a submergence and this sand was exposed as a result of the last emergence. Since then some wind-blown sand has probably been added to the marine alluvial sands. The fluctuating water-table found in the area under present-day climate may be modifying the "carbonaceous sandstone," but is not considered to be the causal agent. The following evidence is advanced to support this hypothesis:—

(1) Pieces of wood were found at a depth of 11 ft. in the brown sand beneath the carbonaceous layer by hydrologists working in the area.

(2) During the digging of the pit in Portion 610 some small pockets of white sand were encountered in the black "carbonaceous sandstone." These pockets were unconsolidated and easy to dig. Such pockets would not be expected if consolidation were resulting from fluctuations in the water-table.

(3) There are extensive outcrops of this "carbonaceous sandstone" on Coolum beach between tide levels (Fig. 2). This would seem to indicate that they are remnants of a previous geological era.

Type 32 is an unusual and somewhat variable type. At the time of the survey it was thought that the carbonaceous sandstone did not underlie it. However, later investigations by McDonald and von Stieglitz have established the fact that the carbonaceous sandstone does underlie it. In our investigations of this type we found mostly a surface horizon of 6–12 in. of golden sand overlying white sand to a depth of approximately 4 ft. Numerous ferruginous nodules occur in the golden sand in certain areas and these have the appearance of having been deposited from solution around roots or stems and so can be classified as Rhizo concretions (Bryan 1952).

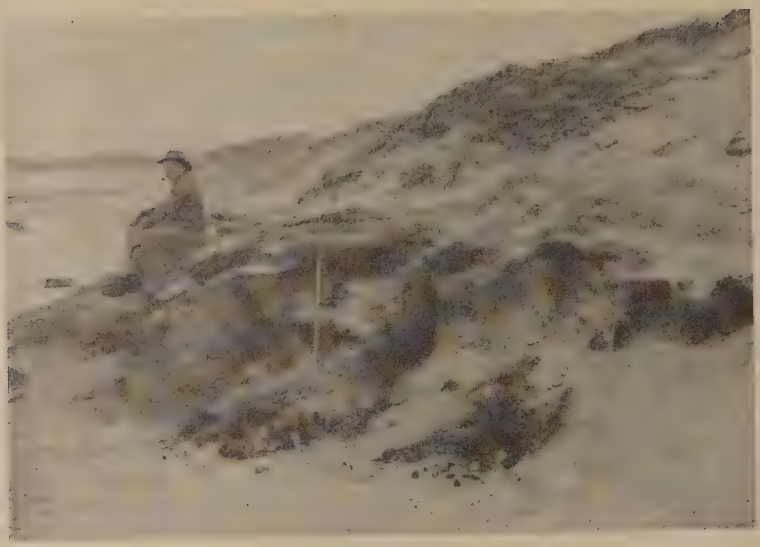

Fig. 2.

Outcrop of "Carbonaceous Sandstone" on Coolum Beach.

These concretions appear to be in the formative stage in certain locations and in others to be due possibly to a disintegration of a previously cemented layer of them.

An interesting phenomenon associated with this soil type is the fact that the vegetation in the early summer months is all of the same colour as the sand of the surface horizon, so areas of type 32 can be located by eye from the summit of Mt. Peregian. No explanation of this phenomenon will be attempted. It does not appear to be a form of chlorosis of the vegetation.

(3) Group 3.

This group comprises the soils encountered in the extensive drainage lines of the area surveyed. Two soils have been named at the series level. These are the Perry Sandy Loam and the Weyba Peaty Sand. Soils of this group have several features in common. These are:

(1) The presence of a water-table at or just below the surface for most of the year.

(2) A hummocky micro-relief produced by erosion.

(3) A peaty surface horizon in the form of a dense root mass combined with decomposing swamp vegetation.

The group as a whole and in particular the tea-tree swamp soils warrant further study to give a clear picture of soil variation existing in drainage lines. The presence of a water-table would make this a difficult

Table 2.

CHEMICAL ANALYSES OF COOLUM SOIL TYPES.

Soil Type	Horizon	Depth	pH H_2O 1 : 2·5	Available P_2O_5 B.S.E.S. ppm	Replaceable Bases									Total N	Organic Carbon	C/N
					m-equiv. per 100 g.					Percentage of Total						
		in.			Ca++	Mg++	Na+	K+	Total	Ca	Mg	Na	K	%	%	
Peregian Sandy Loam. Forest vegetation site. Portion 610	A1	0–6	5·4	8	0·55	0·50	0·11	0·08	1·24	44·35	40·33	8·87	6·45	0·05	1·02	20.5
	A2	6–18	5·6	8	0·20	0·34	0·08	0·03	0·65	30·77	52·31	12·31	4·61	0·04	0·38	9·5
	A2	18–30	5·5	12	0·20	0·61	0·09	0·05	0·95	21·05	64·21	9·47	5·27	0·04	0·18	4·5
	B1	30–36	5·5	6	0·15	0·90	0·13	0·03	1·21	12·40	74·38	10·74	2·48	0·03	0·26	8·7
		36–40			Nodular and concretionary zone											
		40–60	4·9	6	0·25	1·81	0·21	0·03	2·30	10·87	78·69	9·13	1·31	0·06	0·35	6.0
		60–72	4·9	8	0·35	2·19	0·30	0·04	2·88	12·15	76·04	10·42	1·39	0·02	0·08	4·0
Wallum Sand. Banksia area	A1	0–12	4·8	8	0·35	0·39	0·07	0·07	0·88	39·77	44·33	7·95	7·95	0·03	0·42	14·0
	A2	12–36	5·0	10	0·55	0·16	0·05	0·03	0·79	69·62	20·25	6·33	3·80	0·01	0·13	13·0
	A2	36–72	5·4	8	0·45	0·05	0·05	0·04	0·59	76·27	8·47	8·47	6·78	0·01	0·09	9·0
Weyba Sandy Loam. " Peaty heath "	A1	0–12	4·7	8	1·25	1·85	0·44	0·16	3·70	33·78	50·0	11·89	4·33	0·23	3·14	13·6
	A2	12–30	5·4	12	0·70	0·54	0·06	0·04	1·34	52·24	40·30	4·48	2·98	0·04	0·18	4·5
	B1	30–36	5·0	8	1·05	0·95	0·08	0·04	2·12	49·53	44·81	3·77	1·89	0·04	0·68	17·0
Coolum Sand. Normal heath	A1	0–4	4·8	18	0·50	0·26	0·11	0·07	0·94	53·19	27·66	11·70	7·45	0·05	0·78	15·6
	A2	4–24	5·1	10	0·60	0·34	0·06	0·03	1·03	58·25	33·01	5·83	2·91	0·07	0·12	2·0
	*	24–60	4·7	12	0·90	1·00	0·55	0·03	2·48	36·29	40·32	22·18	1·21	0·04	2·01	50·0
A Tea-tree Soil		0–12	5·0	260	5·10	8·49	2·20	0·55	16·34	31·21	51·96	13·41	3·37	0·75	17·22	22·9

* Carbonaceous sandstone layer.

assignment. An auger was put down to 72 in. in one position (see appendix) and the profile described suggests the presence of a buried soil below 42 in.

VIII. CHEMICAL PROPERTIES.

Chemical analyses (Table 2) indicate that all soil types mapped are grossly deficient in major nutrients. This is understandable considering the sandy nature of the parent material and the losses suffered by leaching from the fairly high annual rainfall. All soils are medium acid to very strongly acid in reaction, the pH ranging from 5·6 to 3·5.

Total nitrogen is low in all samples with the exception of the A_1 horizon of Weyba Sandy Loam, for which a figure of 0·23 per cent. N was recorded. For most samples total nitrogen was less than 0·05 per cent. Organic carbon is low in most samples, the maximum figure recorded being 3·14 per cent. in the A_1 horizon of the Weyba Sandy Loam. The C/N ratio is variable, ranging from 2·0:1 in the A_2 horizon to 50·0:1 in the "carbonaceous sandstone" of Coolum sand.

Available phosphorus is very low, in no case being greater than 18 p.p.m. P_2O_5 (BSES method).

Exchangeable metal cations are low, the highest figure recorded being 3·70 m.-equiv. per 100 g. in the A_1 horizon of the Weyba Sandy Loam. Generally speaking, calcium and magnesium together comprise 80–90 per cent. of the cations, the total of which is often less than 1 m.-equiv. per 100 g. Sodium is invariably present in greater amounts than potassium, but in no case is the amount of sodium sufficiently high to have any adverse effect on plant growth. Though cyclic salt must be deposited in large quantities over the area, it is probably leached out rapidly owing to the sandy nature of the soils.

Moisture equivalent and wilting point figures have been determined (Table 3) for soil types at present being used for experimental purposes, but the inherent weakness of the methods when dealing with very sandy soils means that the figures obtained have little significance. In some cases the moisture equivalent recorded is less than the wilting point. There is little doubt that the range of available moisture is narrow on all soil types, with the possible exception of those having a peaty surface.

As stated above, these remarks refer to the "mapped" soil types. However, in the appendix are analytical figures relating to a sample of the surface 12 in. of one of the tea-tree areas. This soil, though strongly acid in reaction, is high in organic matter and well supplied with the major plant nutrients. Where it has been possible to drain such soils in the district, sugar-cane has been grown successfully.

Table 3.

MECHANICAL ANALYSES OF COOLUM SOIL TYPES.

Soil Type	Lab. No.	Depth	Mechanical Analyses							Texture	Moisture Equivalent %	Wilting Point
			Loss on acid %	Moisture %	Coarse sand %	Fine sand %	Silt %	Clay %	Total			
Peregian Sandy Loam. Forest vegetation site. Portion 610	A1	0–6	1·0	0·52	48·92	35·00	6·85	6·60	98·89	LS	4·7	4·2
	A2	6–18	0·89	0·58	52·21	30·95	12·60	3·07	100·30	LS	3·9	3·4
	A2	18–30	0·92	0·67	53·79	25·23	14·95	3·10	98·66	LS	5·5	4·7
	B1	30–36	0·92	0·76	47·96	27·41	8·50	15·35	100·90	SL	7·2	6·3
		36–40	Nodular and concretionary zone									
		40–60	1·42	2·47	19·71	16·15	31·22	29·97	100·94	SiCl	28·9	23·3
		60–72	1·60	2·4	20·00	12·61	17·40	45·80	99·81	C	33·7	23·5
Wallum Sand. Banksia area	A1	0–12	0·74	0·36	94·47	1·96	0·27	3·95	101·75	S	Values unreliable	
	A2	12–36	0·29	0·06	93·16	5·12	1·15	6·70	100·48	S		
	A2	36–72	0·29	0·06	92·34	5·11	2·07	0·80	100·67	S		
Weyba Sandy Loam. "Peaty heath"	A1	0–12	1·57	4·68	59·81	10·64	9·67	13·60	99·97	SL	Values unreliable	
	A2	12–30	0·19	0·06	93·93	2·96	0·60	3·0	100·74	S		
	B1	30–36	0·27	0·28	93·18	3·51	0·30	3·2	100·74	S		
Coolum Sand. Normal heath	A1	0–4	0·26	0·34	80·64	9·25	3·12	5·15	98·76	S	Values unreliable	
	A2	4–24	0·09	0·06	88·93	8·99	0·12	3·80	101·99	S		
	*	24–60	0·63	0·74	77·78	8·52	4·17	7·45	99·29	LS		
A Tea-tree Soil		0–12	3·57	8·42	28·35	5·59	19·7	22·35	87·98			

* Carbonaceous sandstone layer.

IX. DISCUSSION.

Any large-scale development of wallum areas is dependent upon the successful establishment of improved pastures. The factors limiting this establishment are chemical infertility and poor moisture relationships. In the soils mapped the poor moisture relationship is represented by the two extremes: inability to hold "available moisture" in the case of the Aeolian and Marine Alluvial Sands, and continuous waterlogging of the Acid Swamp soils.

In practice it is difficult to increase the water-holding capacity of soils, and until irrigation is shown to be practicable, production from the Aeolian and Marine Alluvial Sands will be closely correlated with rainfall received, irrespective of the level to which chemical fertility is raised.

The waterlogged conditions responsible for the formation of the acid swamps have resulted in the production of a group of soils whose surface horizons are loams or sandy loams high in organic matter. Such soils if drained should possess a reasonable range of "available moisture". For this reason the acid swamp soils as a group warrant more detailed investigation with a view to determining existing soil variation, and the economics of drainage and clearing. Drainage must be envisaged on the basis of whole catchments and not on the basis of individual blocks. Sugar-cane is already being grown successfully on small areas of soil of a similar nature within the wallum area.

The Lateritic-Podsolic soils, though sandy, are less "droughty" than the Aeolian and Marine Alluvial Sands and production from soils of this group should prove reasonably satisfactory if the chemical fertility can be improved economically.

X. ACKNOWLEDGEMENTS.

Our thanks are due to Mr. C. R. von Stiegiltz (Agricultural Chemist) who initiated the survey and whose continued interest and advice has been largely responsible for the completion of this report. We are indebted to Mr. A. McDonald (Asst. Soils Technologist) for having numerous botanical species identified, and for the completion of the soil map. We desire to place on record our appreciation of the generous assistance given by the late R. W. Clark (formerly Soils Technologist). Mr. Clark spent a week in the field with the authors, and his advice and experience were drawn on widely in compiling this report.

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APPENDIX.

The following profile descriptions cover all soil types encountered during the survey.

Lateritic Podsolic Group.

Type 100—Peregian Loamy Sand.

A_1 0–8″ Light grey (5Y 7/0) to grey (5Y 6/0) loamy sand, loose and friable when moist, firm when dry.

A_2 8″–20″ Pale yellow (5Y 7/3) to light yellowish brown (2.5Y 6/4) loamy sand, loose and friable when moist.

B_1 20″–26″ Yellow brown (10YR 5/6) to olive yellow (2.5YR 6/6) (with dark red (2.5YR 3/6) to red (10R 4/6) mottle), sandy loam—sandy clay loam to sandy clay. Moderately friable.

B_{21} 26″–32″ Red (2.5YR 4/6) with white (10YR 8/1) mottle, medium to heavy clay, weakly prismatic.

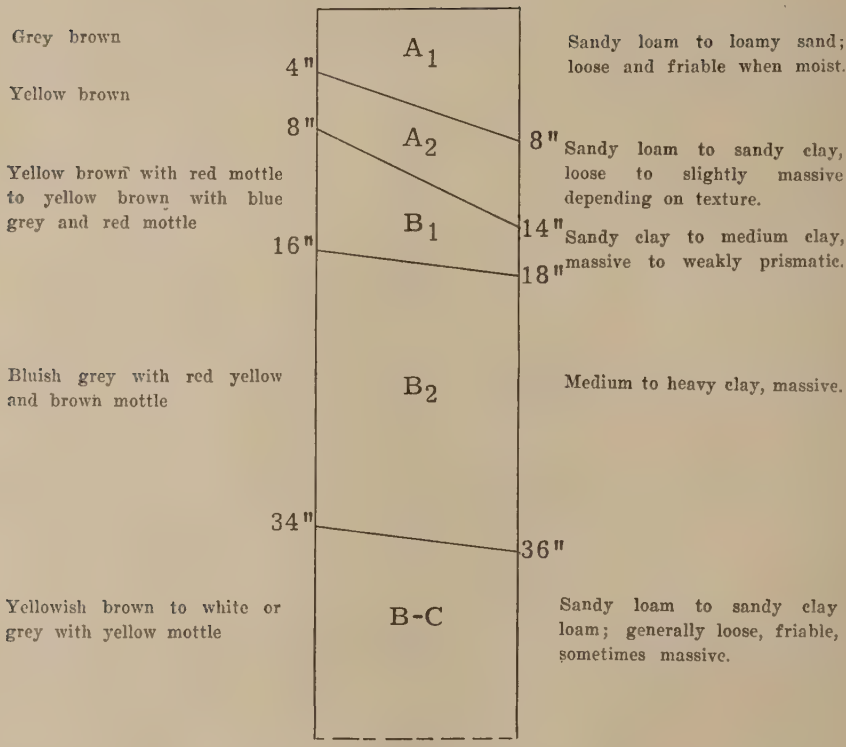
B_{22} 32″–72″ Red (10R 4/6) and white mottled medium to heavy clay, weakly prismatic.

N.B.—Mechanical analysis on B_{21} horizon places the texture erroneously in the silty clay loam class. The silt and clay fractions after agitation in the sedimentation cylinder became a flocculated gelatinous mass which remained high up in the cylinder even after overnight standing.

The analysed sample was taken from a pit situated about 40 yd. south of Portions 469-470 corner in an area which has since been bulldozed.

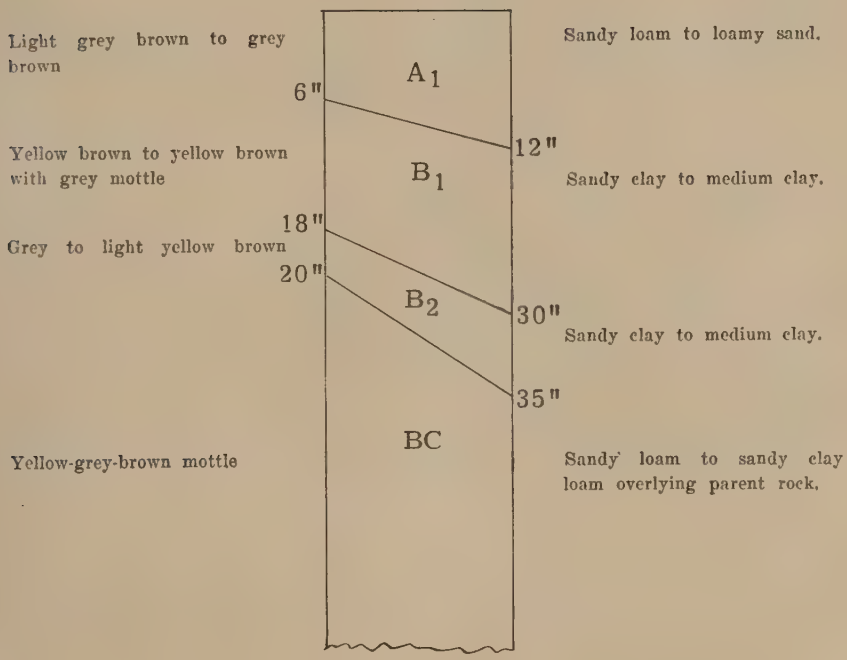
The nodular phase, which has not been mapped separately, contains a cemented layer of nodules and concretions approximately 4 in. thick at a depth of 36 in.

TYPE 10S—MAROOCHY LOAMY SAND.


Grey brown
4"
A1
Sandy loam to loamy sand; loose and friable when moist.
Yellow brown
8"
A2
8"
Sandy loam to sandy clay, loose to slightly massive depending on texture.
Yellow brown with red mottle to yellow brown with blue grey and red mottle
B1
14"
Sandy clay to medium clay, massive to weakly prismatic.
16"
18"
Bluish grey with red yellow and brown mottle
B2
Medium to heavy clay, massive.
34"
36"
Yellowish brown to white or grey with yellow mottle
B-C
Sandy loam to sandy clay loam; generally loose, friable, sometimes massive.

No samples of this soil type have been analysed. The depths of the horizons vary appreciably, as will be seen from the diagram. In analysis and fertility, this type would be expected to be very similar to the Peregian Loamy Sand.

TYPE 20—UNNAMED—COMPLEX.



A fair amount of variation can be expected in this soil type. The depth at which the parent rock is encountered varies from approx. 18 in. to over 6 ft. Type 20 is found fringing Mt. Peregian on the N.S. & S.

Perhaps two or three soil types could have been delineated in the area mapped as type 20. However, the acreage involved is small, and as none of the soils mapped as type 20 is likely to become of agricultural importance, it was decided to make the one soil type, allowing a fair amount of variation in the depth at which the parent material is encountered and in the texture of the horizons.

Aeolian and Marine Alluvial Sand Group.

Type 31—Coolum Sand.

A_1	0–4″	Light grey (5Y 7/0) to grey (5Y 6/0) sand, loose single grain.
A_2	4″–24″	White (5Y 8/0) to light grey (5Y 7/0) sand, loose single grain.
Geological layer carbonaceous sandstone	24″–60″	Dark grey (2.5Y 4/0) to black (2.5Y 2/0) loamy sand, compact to indurated *in situ;* crumbles readily on exposure.

Analysed sample from Pit on "Big Plain" on Portion 610.

Type 30—Wallum Sand.

A_1	0–12″	Light grey (5Y 7/0) sand, single grain, loose.
A_{21}	12″–36″	White (7.5YR 8/0) sand, single grain, loose.
A_{22}	36″–72″	White (7.5YR 8/0) sand, single grain, loose.
Geological layer	>72″	As in Coolum sand.

Analysed sample taken from sand dune to east of Mt. Emu.

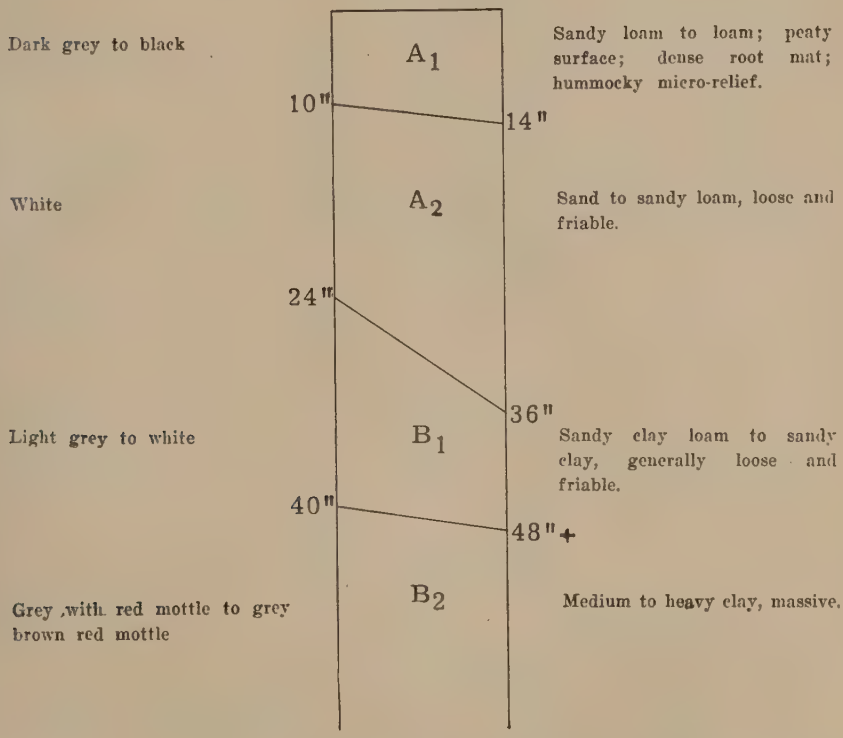
Acid Swamp Soil Group.

Type 40—Weyba Sandy Loam.

A_1	0–12″	Very dark grey (10YR 3/0) organic sandy loam, spongy due to dense mat of roots.
A_2	12″–30″	Light grey (5Y 7/0) with odd dark specks sand, single grain, loose.
B_1	30″–36″	Dark grey (10YR 4/0) to black (2.5Y 2/0) sand to loamy sand; frequently loose and friable but sometimes "carbonaceous sandstone."
Usually water perched on carbonaceous sandstone		

This is peaty heath. Analysed sample taken from area east of Mt. Peregian and a few chains north of enclosed experimental area.

TYPE 110 (SWAMPY)—PERRY SANDY LOAM.



A very small area of a better drained Perry Sandy Loam runs around the foothills of the forest areas in Portion 610. It resembles very closely the above profile but the A_1 horizon is a light grey to grey loamy sand. The A_2 horizon may go to a depth of 48 in. The more elevated topographical position results in a moderately well drained surface horizon without the hummocky micro-relief of the above profile.

Tea-tree Profile (1).

A_1 0–18″ Black loam; dense root mass and decomposing organic material; spongy.

A_2 18″–22″ Grey brown sandy loam.

B 22″–42″ Grey heavy sandy clay, massive and compact.

A? 42″–54″ Grey loamy sand, loose.

B? 54″–72″ White heavy clay, dense, massive and compact.

Only one tea-tree swamp area in true drainage lines examined. This had profile shown above. Water below 18 in.

Approximate position of this hole—Portion 610, W55 S16.

The white heavy clay horizon below 54 in. is thought to be almost pure kaolin. Few pieces of quartz found. Thought to be present-day profile superimposed on a pre-existing profile, so A? and B? can be called geological layers.

Tea-tree Profile (2).

A_1 0–9″ Dark grey sandy loam to loam, fairly loose.

A_2 9″–14″ Grey to dark grey light to medium clay, loose.

B_1 14″–24″ Grey brown with yellow brown mottle medium clay, massive.

B_2 24″–32″ Blue grey with yellow brown mottle heavy clay, massive.

B_3 32″–56″ Blue grey heavy clay, massive.

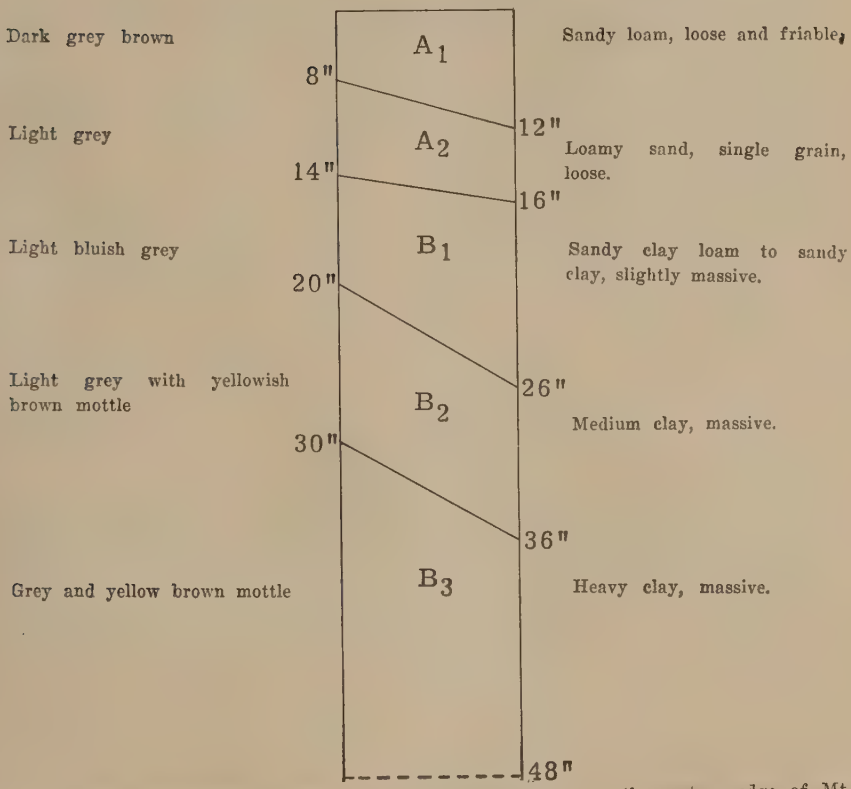
B–C 56″– Grey light clay, loose.

This profile represents soil types found in a small tea-tree area on Portion 470. South of Mt. Peregian and immediately west of pineapple area. Hole bored from top of puff. If boring from shelf, first horizon encountered is that shown above as A_2 and in this case it is very dark grey to black in colour.

Tea-tree profile (1) considered to be more representative of bulk of the tea-tree area than tea-tree profile (2). Tea-tree profile (2) would seem to be a specialised case of a perched basin which has a high water-table for only a couple of months each year.

Unclassified.

TYPE 120.



This represents an average profile of the small area on the eastern edge of Mt. Peregian. The area is unshaded on the map and will be one of the unclassified soils.

Unclassified (2).

0–6″ Yellow brown light clay, friable.
6″–24″ Yellow brown with grey brown mottle medium clay, slightly massive.
24″–32″ Grey with yellowish brown mottle sandy clay to medium clay, massive.
32″–42″ White sand, single grain, loose.

The above soil type is found in a small area on the western edge of Portion 610. It is surrounded by areas of peaty heath and supports a vegetation of stunted apple and tumble-down grey gum.

This soil has not been classified and the area it covers is unshaded on the map.

Approximate position W195 S55.

Unclassified (3).

0–3″ Grey brown loamy sand, loose.

3″–26″ Yellow brown sandy loam.

26″–36″ White with yellow brown mottle sandy loam.

36″–42″ White with yellow brown mottle sandy clay, massive.

Another unclassified soil, the small area of it being unshaded on the map. Approximate position W143 S0 in Portion 610.

About 60 chains west of the hut on Portion 468 on the boundary of Portions 610 and 468. Of little or no importance.

A CROWN ROT OF STRAWBERRY CAUSED BY *PHYTOPHTHORA PARASITICA*

By G. J. P. McCARTHY, B.Agr.Sc. (Pathologist), and D. S. TEAKLE, B.Agr.Sc. (Assistant Pathologist), Pathology Branch, Division of Plant Industry.

SUMMARY.

Phytophthora parasitica **was isolated from an unusual type of crown rot. Plants successfully inoculated showed a brown rot of the crown and a red-brown cortical rot of roots near the crown. Inoculation of green fruit produced a firm brown rot not seen in the field.**

The low incidence of the disease suggests that rotation will provide adequate control.

I. INTRODUCTION.

Since February 1955 six outbreaks of an unusual type of crown rot have been detected in strawberry plants of the Phenomenal variety in Queensland. The disease has been investigated and it has been found that *Phytophthora parasitica* Dast. is responsible for the trouble. This fungus has been reported elsewhere causing a fruit rot of strawberry (Felix 1953), but apparently not a crown rot. In view of this fact, information obtained in field investigations and glasshouse experiments is now recorded.

II. SYMPTOMS.

In the field the crown rot is typified by the rapid wilting and browning-off of mature strawberry plants (Fig. I). Diseased plants occur either singly or in small scattered groups.

The symptoms on individual plants are first apparent on the older outside leaves, which become flaccid and lie prostrate instead of standing erect. Often these leaves acquire a khaki colour when they die rapidly. As the disease progresses the younger central leaves also wilt and die.

In the crown a brown rot develops at the base, and often a red-brown discoloration of vascular tissue extends away from the rot into healthy tissue. In advanced stages of attack all the crown and foliage turn brown, and on such plants the roots are invariably blackened and rotted.

Fig. 1.

Strawberry Plant Affected in the Field with Crown Rot caused by *Phytophthora parasitica.*

III. ISOLATION AND IDENTIFICATION OF ORGANISM.

Isolations were made from affected plants using various techniques. A species of *Phytophthora* was consistently isolated when rotting crown tissue was plated onto potato dextrose agar and water agar or inserted into apple fruit. The fungus was less regularly obtained from roots inserted into apple, and was never isolated when rotted roots were plated onto water agar.

A study of the species of *Phytophthora* involved showed that it readily produced papillate sporangia and spherical chlamydospores when host tissue or agar blocks containing the fungus were irrigated. Oogonia, however, were not produced in plate cultures on corn meal, water, and potato dextrose agars. The fungus was found to grow slightly at 36·5°C., but not at 39°C. In these features and in cultural characters the fungus was indistinguishable from isolates of *P. parasitica* obtained from other hosts in Queensland, and all evidence points to it being this species.

IV. PLANT INOCULATION EXPERIMENTS.

In a preliminary experiment in 1955 using 12 potted strawberry plants, four were inoculated without wounding, four were inoculated after scarifying the base of the crown, and two wounded and two unwounded were left uninoculated. One wounded inoculated plant wilted in 19 days and one unwounded inoculated wilted in 30 days. *P. parasitica* was reisolated from both plants.

In a second experiment plants were raised from first runners rooted in sawdust in order to ensure comparative freedom from nematodes (Colbran 1957). On February 22, 1957, six weeks after transplanting into pots of steamed soil, crown and root inoculations were performed using sterile corn meal sand (Riker and Riker 1936) on control plants and corn meal sand inoculated two weeks previously with *P. parasitica* on others. Crown inoculation was carried out by inserting lumps of inoculum into the soil on two sides of the strawberry crown. Soil was then pulled over the inoculum to avoid its rapid desiccation. Root inoculation consisted in temporarily removing the soil and plant from the pot and placing lumps of inoculum at the bottom and at four places at the circumference about half way up the pot. There were seven plants in each treatment. Results appear in Table 1.

Table 1.

DATE OF APPEARANCE OF WILT SYMPTOMS ON STRAWBERRY PLANTS INOCULATED ON FEBRUARY 22, 1957, WITH A CULTURE OF *P. parasitica*.

Plant.	Crown Inoculation.	Root Inoculation.
1	February 27	March 29
2	February 27	April 1
3	February 27	May 9 (partly wilted)
4	March 14	*
5	March 18	*
6	March 19	*
7	*	*

* Healthy on May 9.

Six crown inoculated plants and two root inoculated plants wilted completely before May 9, when the experiment was terminated. One root inoculated plant was partially wilted on this date. Isolations from the crowns into apple fruit and onto water agar confirmed that *P. parasitica* was responsible for the rot. Sporangia and chlamydospores typical of the fungus were obtained when rotting roots and petioles were surface sterilized for 30 seconds in 0·1% mercuric chloride and placed in water.

All fourteen control plants remained healthy except one crown inoculated plant which died from crown and root rot about March 10. On this plant there was a marginal leaf scorch which was distinct from the wilt of the entire leaf in Phytophthora-affected plants. Species of *Fusarium* and fungi other than *P. parasitica* were associated.

Disease symptoms exhibited by the successfully inoculated plants were foliage wilt progressing from the older to the younger leaves; collapse of the outer leaf stalks onto the rim of the pot; a dark brown rot at the base of some of the collapsed leaf stalks; a brown rot starting at the base of the crown and eventually involving the whole crown; a red-brown cortical rot of the roots in the vicinity of the crown.

V. FRUIT INOCULATIONS.

When green fruit were inoculated with a crown rot isolate of the fungus, a firm brown rot was produced. "Leather rot" of strawberry fruit caused by species of *Phytophthora* has not been recorded occurring naturally in Queensland.

VI. DISCUSSION.

The evidence from field investigations and pathogenicity experiments is that *P. parasitica* is the cause of a crown and root rot of strawberry plants. The disease has been recorded in the field from September to February when the prevailing high temperatures favour activity of the fungus. Waterlogging of the soil does not appear necessary to predispose plants to infection as outbreaks have occurred following periods of relatively dry weather.

Field outbreaks of the disease are rare and the proportion of infected plants does not usually exceed 5 per cent. However, more than 90 per cent. crown rot occurred in one planting being kept for the production of runners. In this case the only other market crop being grown on the property was rhubarb, which also was badly affected by crown rot caused by *P. parasitica*. Possibly the unusual severity of this outbreak was due to build-up of inoculum by continually growing two susceptible crops. On this property *P. parasitica* was isolated from lesions on the roots of strawberry runners; this demonstrates the danger of taking runners from affected patches.

At present the importance of the disease does not warrant the adoption of control measures other than crop rotation with resistant plants and avoidance of planting material from affected patches. Losses have occurred in the warmer part of the year after the main cropping period has passed. Furthermore, in this State the strawberry is treated as an annual, and loss of plants does not affect the following year's stand as would be the case in cooler climates where a longer period of establishment is preferred.

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TECHNICAL NOTES

BORON STUDIES ON A KRASNOZEM SOIL IN QUEENSLAND

I. INTRODUCTION.

Boron deficiency symptoms have been recorded over the past few years in a number of vegetable crops in the Redlands district, near Brisbane, which is the main vegetable growing area in Queensland. The deficiency has been evident particularly under conditions of moderate to heavy liming. Most growers in the affected area now apply borax either in fertilizer mixtures or in foliage sprays.

A field trial was conducted at the Redlands Experiment Station, Ormiston, to obtain information on the boron status of the main Redlands soil type, the changes in available (water-soluble) boron that occur during the growing period, and the uptake of boron by an indicator plant—beetroot.

II. SOIL AND CLIMATE.

The soil of the trial area falls into the Great Soil Group Krasnozem (Stephens 1956). It shows considerable evidence of lateritisation. Iron concretions occur extensively below 12 in., though their distribution is somewhat haphazard. The profile description to 48 in. is as follows:—

A	0–10″	Brown loam; loose crumb/clod.
B_1	10″–17″	Red brown clay loam; loose clod, becoming more compact with depth.
B_2	17″–26″	Red brown clay loam.
B_3	26″–48″	Dark red clay with iron concretions; compact structure.

The soil had not been limed and was acid in reaction. A composite sample of 0–10 in. from all plots before treatment showed the following composition:—

pH	5·7
Total N (%)	·14
Available P_2O_5 (p.p.m.)	28
Replaceable K (m.-equiv. %)	·47
Total replaceable bases (m.-equiv. %)	16·6
Available boron (p.p.m.)	·10

The Station receives heavy monsoonal rain during the first three months of the year and considerable leaching of plant nutrients takes place during this period. Cropping of one type or another is practised throughout the year, and the trial reported here was conducted after the wet season had ended to minimise the effect of transfer of plant foods by high rainfall.

III. EXPERIMENTAL.

The trial was conducted on a block of one-tenth of an acre. There were 4 replications of the following five treatments:—

A. Control

B. 10 lb. borax per acre

C. 30 lb. borax per acre

D. 50 lb. borax per acre

E. 100 lb. borax per acre

The beetroot seed was planted on Apr. 21, 1956, and thinning was carried out on May 10. Borax treatments were given on May 20, the borax being dissolved in water and applied to the soil with a watering can to ensure as even a distribution as practicable.

To correct a possible molybdenum deficiency, all plants were sprayed on May 30 with a solution of $\frac{1}{2}$ oz. ammonium molybdate to $3\frac{1}{2}$ gal. water. At fortnightly intervals for two months after treatment, soil samples were taken from each plot for the determination of boron.

Before harvesting was commenced, the youngest two leaves from four plants in each plot were collected and oven-dried for boron analysis.

Analyses were conducted according to the method suggested by Dible, Truog and Berger (1954), which is as follows:—

Available Soil Boron.—Place 20 g. (air-dried) soil in a 250 ml. Erlenmeyer flask free from boron, add 40 ml. water and reflux for 5 minutes. Add 2 drops conc. $CaCl_2$ solution, stir and centrifuge until clear. Take 1 ml. aliquot and proceed with the colour development procedure.

Boron in Plant Tissues.—Place a 1 g. sample of plant material, oven-dried and ground, in a porcelain crucible and ash in a muffle furnace at 550 deg. C. Dissolve the ash in 5 ml. 0·1N HCl and dilute with water to 50 ml. Take 1 ml. aliquot and proceed with the colour development procedure.

Colour Development Procedure.—Place a 1 ml. aliquot of the water solution, containing 0·0–2·0 boron, in a 250 ml. beaker (boron-free). Add 4 ml. curcumin-oxalic acid solution (0·04 g. curcumin and 5 g. oxalic acid dissolved in 100 ml. ethyl alcohol), and mix thoroughly by rotating the beaker. Evaporate on a water-bath at 55 ± 3 deg. C., and continue to bake the residue at the same temperature for a minimum of 15 minutes to ensure complete dryness. Cool and add 25 ml. 95% ethyl alcohol. Centrifuge or filter the solution and read colorimetrically, using a 540μ filter. Determine the boron concentration by reference to a standard curve.

IV. RESULTS AND DISCUSSION.

(1) Changes in Soil Boron.

The results of the soil analyses are shown in Tables 1 and 2 and the decrease in soil boron during growth is depicted in Fig. 1.

Table 1.

Boron Content (p.p.m.) of Soil in Each Plot at Fortnightly Intervals.

Date.	Control.				10 lb./acre.				30 lb./acre.			
June 3	·12	·32	·32	·32	1·20	·96	1·24	1·08	3·04	1·52	3·60	4·24
June 17 ..	·16	·16	·36	·28	·88	1·28	1·52	1·28	2·32	1·28	2·52	2·72
July 1	·24	·48	·24	·52	·60	1·08	1·52	1·12	2·12	1·60	2·40	2·16
July 15 ..	·32	·32	·24	·34	·16	·72	1·60	0·32	2·24	1·64	1·92	3·60
July 29 ..	·44	·12	·08	·24	1·08	1·08	·96	2·92	1·88	1·36	1·36	2·52

Date.	Control.				50 lb./acre.				100 lb./acre.			
June 3	·12	·32	·32	·32	5·28	3·28	6·56	3·76	6·64	8·00	7·36	6·88
June 17 ..	·16	·16	·36	·28	8·80	2·24	4·32	6·00	5·82	5·60	8·80	4·28
July 1	·24	·48	·24	·52	5·04	2·84	2·96	3·20	6·00	4·40	6·64	4·40
July 15 ..	·32	·32	·24	·34	2·40	3·56	3·12	2·32	2·64	3·32	3·56	2·92
July 29 ..	·44	·12	·08	·24	2·64	2·44	4·56	2·36	1·88	4·08	2·80	3·04

Table 2.

Table of Equivalent Means—Borax Content (p.p.m.) of Soil.

Treatment.	3–6–56.	17–6–56.	1–7–56.	15–7–56.	29–7–56.
100 lb./acre Borax ..	7·24	5·92	5·27	3·09	2·82
50 lb./acre Borax ..	4·57	4·79	3·39	2·82	2·88
30 lb./acre Borax ..	2·88	2·14	2·19	2·24	1·70
10 lb./acre Borax ..	1·10	1·20	1·02	·81	1·35
Control	·25	·22	·35	·30	·18

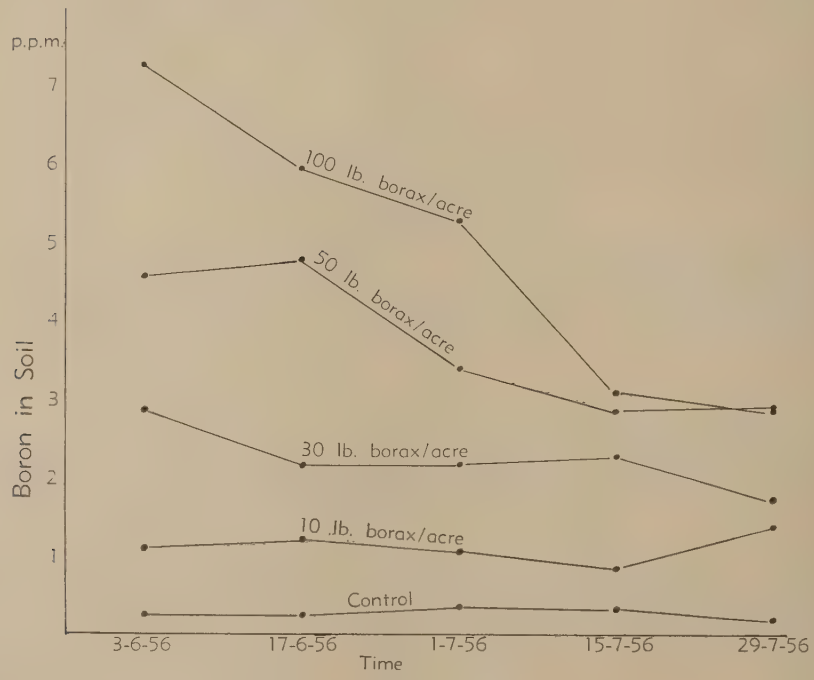

Fig. 1.

Boron Content of Plots at Fortnightly Intervals After Application of Borax.

There is little change in water-soluble soil boron either in the control plots or in those receiving 10 lb. borax per acre. At higher rates of application there is a sharp decrease in boron during the first six weeks, after which the decrease is very small. The rise in the curve for the 50 lb. per acre application may be due to sampling error consequent on uneven distribution of the borax at application.

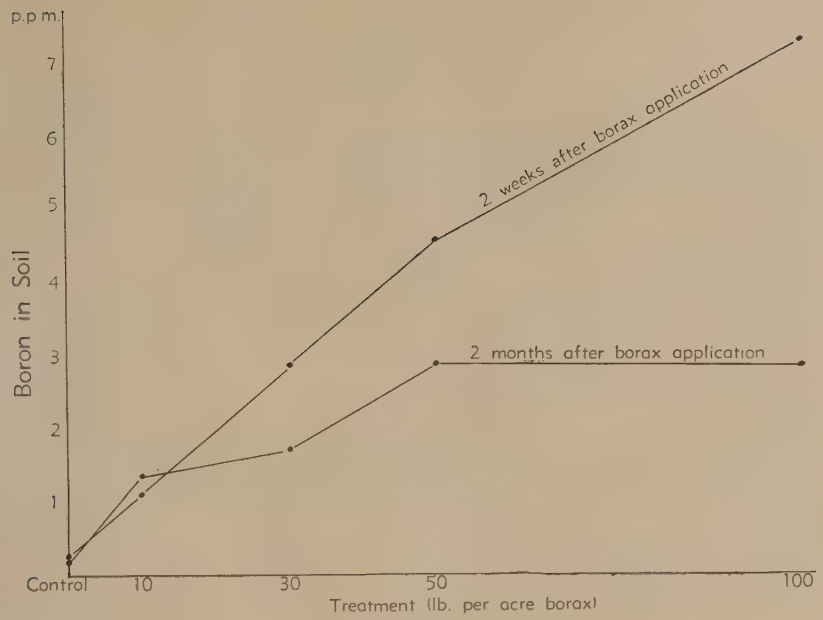

Fig. 2.

Soil Boron Content of Plots at Two Weeks and Two Months After Application of Borax.

Fig. 2 shows the increase in water-soluble soil boron with increasing rate of application of borax at two stages of the trial. Initially, this increase is almost linear, but two months after treatment the curve has a more gradual slope. Loss of boron has occurred in those plots receiving 30 lb., 50 lb. and 100 lb. This loss is attributable to leaching by rain and irrigation water, fixation by the soil, and increased uptake of boron by the plant, the last being the least important.

(2) Uptake of Boron.

The results of plant analyses are given in Table 3 and Fig. 3. Plant boron content rises with increase in rate of application of boron to the soil. The rise in plant boron content was not accompanied by any visible effect on growth or any toxicity symptoms, even when soil boron content was over 7 p.p.m.

Table 3.

PLANT ANALYSES.
(*p.p.m. Boron*).

—	Control.	10 lb./acre.	30 lb./acre.	50 lb./acre.	100 lb. acre.
Replication 1..	21	7	18	22	41
Replication 2..	10	21	21	40	71
Replication 3..	10	19	24	31	60
Replication 4..	16	16	33	24	42
Equivalent Means	13·5	14·4	23·4	28·2	52·7

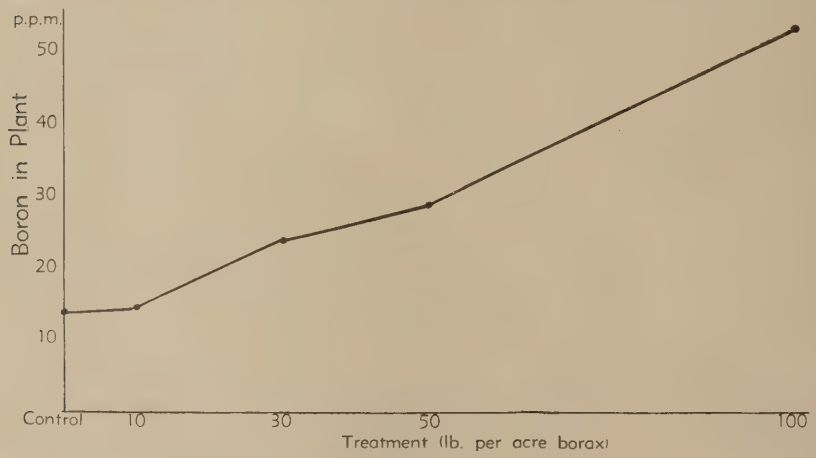

Fig. 3.

Plant Boron Content in Relation to Soil Applications of Borax.

No deficiency symptoms occurred in the control plots. Presumably at the pH of 5·7 the availability of boron in the soil was sufficient to enable normal growth to be made even at a soil boron level which is considered by some workers to be below the critical level.

There were no significant differences between treatments in yield of harvested roots.

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A NOTE ON FOLIAR DIAGNOSIS OF BORON DEFICIENCY IN BEETROOT

A pot trial was conducted with beetroot on Coolum sand to examine the relationship between visual and chemical foliar diagnosis of boron deficiency. Coolum sand is almost completely lacking in major plant nutrients and in trace elements.

Treatments with boric acid solution were given to bring the concentration of boron in the sand to levels ranging from 0·01 p.p.m. to 5·00 p.p.m. The nutrient solution used was one devised by Colwell (1943), and the general procedure followed that suggested by Hewitt (1952). Pots received nutrient solution every second day.

An ammonium molybdate spray was given to all plants at an early stage of growth to rule out the possibility of molybdenum deficiency.

Leaf analysis for boron was carried out when the roots had reached maximum size.

The observations are summarised as follows:—

Treatment.	B in leaf at maturity. (p.p.m.)	Remarks.
Control	15	Severe deficiency symptoms. Death of growing point. Stems growing almost horizontally. Some multiple topping
0·01 p.p.m. B ..	16	Similar symptoms but less severe
0·02 p.p.m. B ..	18	Growth better, but still some necrosis at growing point
0·05 p.p.m. B ..	18	Growth fair
0·10 p.p.m. B ..	27	Growth normal
0·20 p.p.m. B ..	32	Growth normal
0·40 p.p.m. B ..	45	Growth normal
0·80 p.p.m. B ..	83	Growth normal
5·00 p.p.m. B ..	61	Severe toxicity symptoms at first, then normal growth, but smaller than 0·80 p.p.m. plants at maturity

It appears that the minimum leaf content of boron for normal growth is about 20 p.p.m.

Table 1.

Composition of Nutrient Solution.

Salt.	Concentration of Stock Solution.	Ml. of Stock Solution for Each Litre of Nutrient Solution.
KH_2PO_4	1·0M	5
K_2HPO_4	0·2M	5
$MgSO_4 7H_2O$	1·0M	7
$Ca(NO_3)_2 4H_2O$	1·0M	7
$NaNO_3$	1·0M	7
$MnCl_2 4H_2O$	0·20 gm/L	5
$ZnCl_2$	0·10 gm/L	
$CuCl_2 2H_2O$	0·02 gm/L	

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EFFECTS OF GROWTH REGULATING SUBSTANCES ON THE RIPENING OF DETACHED BANANA FRUITS

The ripening effects of 2,4-dichlorophenoxyacetic acid on detached banana fruits were first observed by Mitchell and Marth (1944). They found that when this compound was applied to the exterior of bananas, apples and pears, either as an aerosol or in aqueous solution, the ripening of these fruits was hastened. Bananas treated experimentally by them with this compound ripened 3–8 days sooner than untreated fruit. Ripening so induced was claimed to be extremely even. Further work by Marth and Mitchell (1949) resulted in the observation of an apparent antagonistic effect between applied growth regulating substances and naturally produced ethylene during the ripening processes. Further reference to the ability of 2,4-dichlorophenoxyacetic acid to ripen bananas is made by Marth, Audia and Mitchell (1956). Leopold (1955) suggested that in view of the results of Goldacre, Galsdon and Weintraub (1953) the ripening agent was not 2,4-dichlorophenoxyacetic acid but traces of either 2,4-dichlorophenol or 2,4-dinitrophenol present as impurities.

Experimental Details.

In Queensland, commercial ripening of bananas is done with either ethylene or coal gas applied to the fruit, at constant temperature, in small concentrations. As there is always a risk of explosion with these gases if they are not handled carefully, investigations on hormones were carried out from October 1956 to March 1957 in an endeavour to obtain an alternative method of ripening the locally grown fruit of the variety Cavendish. Fruit for experimental purposes was obtained from the local market, and in each experiment fruit was obtained equally from bunches bearing full fruit and those bearing thin, poorly filled fruit. Sample variability was obviated, as far as possible, by removing hands from each bunch and dividing them, a finger at a time, into the required number of treatments so that each treatment contained similar material.

The various growth regulating substances used were applied to the fruit in aqueous solutions or as emulsions in 15 per cent. ethanol. In all cases a commercial wetting agent was added to ensure uniform wetting of the fruit. Generally the compounds were applied by dipping the fruit into the prepared solutions or emulsions, allowing it to drip dry, and

holding it at either 68 deg. F. (the temperature found by Young, Bagster, Hicks and Huelin (1932) to be the most satisfactory for the ripening of this fruit) or at atmospheric temperatures. In one experiment, the ethyl ester of 2,4-dichlorophenoxyacetic acid was evaporated on a hotplate and the fruit exposed to a concentration of its vapour of 200 p.p.m. for 24 hours in an airtight chamber. Severe skin damage resulted and this method of application was discontinued.

Evaluation of the ripening effect was made by classifying individual fruits according to skin colour and/or firmness of flesh. Firmness was measured by means of a Magness Penetrometer fitted with a $\frac{7}{16}$ in. plunger. One inch was cut from each end of the fruit to be tested and pressure applied to the cut end until the plunger sank to the marked line.

The following growth regulating substances, generally commercial samples, were used in the investigations:—

(1) 2,4-dichlorophenoxyacetic acid.

(2) 2,4-dichlorophenoxyacetic acid (sodium salt).

(3) 2,4-dichlorophenoxyacetic acid (ethyl ester).

(4) 2,4-dichlorophenoxyacetic acid (triethanolamine salt).

(5) 2,4,5-trichlorophenoxyacetic acid (butyl ester).

(6) 2,4-dichlorophenol.

(7) 2,4-dinitrophenol.

(8) 2,4,5-trichlorophenoxypropionic acid.

(9) 2 methyl 4 chlorophenoxyacetic acid (sodium salt).

(10) 2 methyl 4 chlorophenoxyacetic acid (amine salt).

(11) Chloroisopropylphenylcarbamate.

(12) Naphthalene acetic acid.

(13) Parachlorophenoxyacetic acid (sodium salt).

(14) Maleic hydrazide.

Results.

The results were difficult to interpret because of the extreme variability of the materials used. However, it was apparent that some growth regulating substances have a decided influence on the ripening of some

banana fruits. The samples of 2,4-dichlorophenoxyacetic acid, 2 methyl 4 chlorophenoxyacetic acid, and their derivatives, were most effective at concentrations between 200 and 400 p.p.m. but at higher concentrations caused skin damage, the severity of which increased with concentration. Even at concentrations of 200–400 p.p.m., the ethyl ester of 2,4-dichlorophenoxyacetic acid and the butyl ester of 2,4,5-trichlorophenoxyacetic acid caused severe skin damage.

When skin damage did not develop and ripening was accelerated, a satisfactory skin colour failed to appear. The pulp of the fruits was quite soft, as in normal ripening, but the skin retained some of its green pigmentation. Ripe fruit was a blotchy greenish yellow in colour, with some yellowish green areas.

Under commercial ripening conditions ethylene results in very even ripening with little difference between bunches whether they are poorly filled or well filled. Occasionally some fruit is hard to ripen, but as a general rule four days at 68 deg. F. with regular gassing with 1 part per 1,000 of ethylene results in complete and even ripening. Treatment with 2,4-dichlorophenoxyacetic acid, 2 methyl 4 chlorophenoxyacetic acid, and their derivatives, resulted in fruit held at 68 deg. F. ripening in 10–14 days. The resultant ripening, however, was very uneven, individual fruits in a sample often remaining quite hard and green while others were full eating ripe. This phenomenon has also been observed with untreated fruit, but the number of ripe fruit where a sample has been treated is usually greater than where the growth regulating substances have not been used.

In the experiments with 2,4-dichlorophenol and chloroisopropylphenylcarbamate, the treated fruit was consistently less ripe than the other fruit, including the untreated controls. These compounds may be of some value in retarding the ripening rates of bananas during storage and transport. The remaining compounds had no visible ripening effect on bananas in any of the experiments conducted.

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PUCCINIA ARGOPHYLLI SP. N. ON *ARGOPHYLLUM NULLUMENSE* IN QUEENSLAND

In January 1957 a collection of inconspicuously rusted leaves of the scrub tree *Argophyllum nullumense* R. T. Baker was made on "The Lost World," a small rain-forest plateau in the rugged McPherson Range of south-eastern Queensland. *Argophyllum* is a genus of the family Saxifragaceae, tribe Escallonieae. No rust has been recorded from this genus or the related *Quintinia, Abrophyllum, Cuttsia, Polyosma* and *Anopterus.* The rust is therefore considered to be an unnamed species, and is described below.

Puccinia argophylli sp.n.

Aecia yellow, amphigenous, but mainly epiphyllous, sunken in host tissue, orbicular, mostly 0·2–0·4 mm. diam. Aeciospores subglobose or polygonal, 23–27 x 17–20 μ, walls 2–3 μ thick, distinctly verrucose.

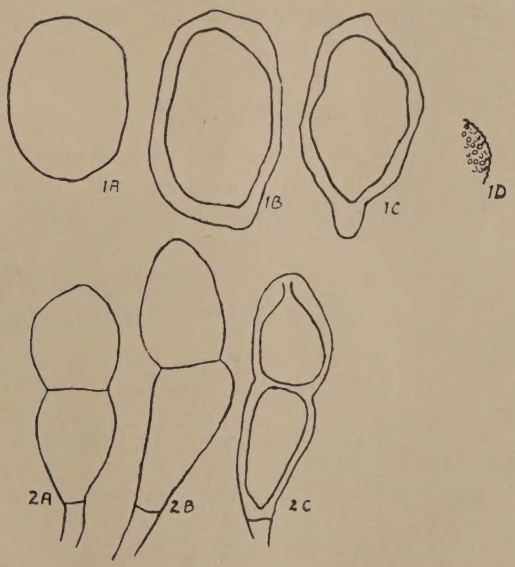

Fig. 1.

Aeciospores and Teliospores of *Puccinia argophylli* sp.n.
1. Aeciospores x 1,000. 1A, outline; 1B, 1C, median optical section; 1D, portion of wall.

2. Teliospores x 500. 2A, 2B, outline; 2C, median optical section.

Telia brown, hypophyllous, protruding through leaf hairs, 0·1–0·2 mm. diam. Teliospores ellipsoidal, constricted at the septum, 60–86 x 20–25 μ, walls smooth, pedicels hyaline, 40–60 μ in length.

In foliage of *Argophyllum nullumense* R. T. Baker, McPherson Range, Queensland, January 26, 1957. Collector, D. S. Teakle.

Aecia flava pro more epiphylla sed etiam amphigena, in textu hostis immersa, orbicularia, pro more 0·2–0·4 mm. diam. Aeciospori subglobosi vel polygoni, 23–27 x 17–20 μ, eorum muri 2–3 μ crassi, distincte verrucosi. Telia brunnea hypophylla extra pilos follii extensa, 0·1–0·2 mm. diam. Teliospori ellipsoidei, septo constricti, 60–86 x 20–25 μ, muris laevibus, pedicellis hyalinis 40–60 μ longis.

In foliis *Argophylli nullumensis* R. T. Baker, McPherson Range, Queensland, January 26, 1957. Leg. D. S. Teakle.

The rust is known only from the one locality. The host plant is for the most part restricted to the McPherson Range and neighbouring ranges.

The type collection has been placed partly with the University of Queensland, Brisbane, and partly with the Commonwealth Mycological Institute, Kew.

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Dr. S. T. Blake, of the Queensland Department of Agriculture and Stock, kindly furnished the Latin diagnosis and supplied information concerning the distribution of the host plant.

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